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AGRICULTURAL MECHANIZATION IN EQUATORIAL AFRICA

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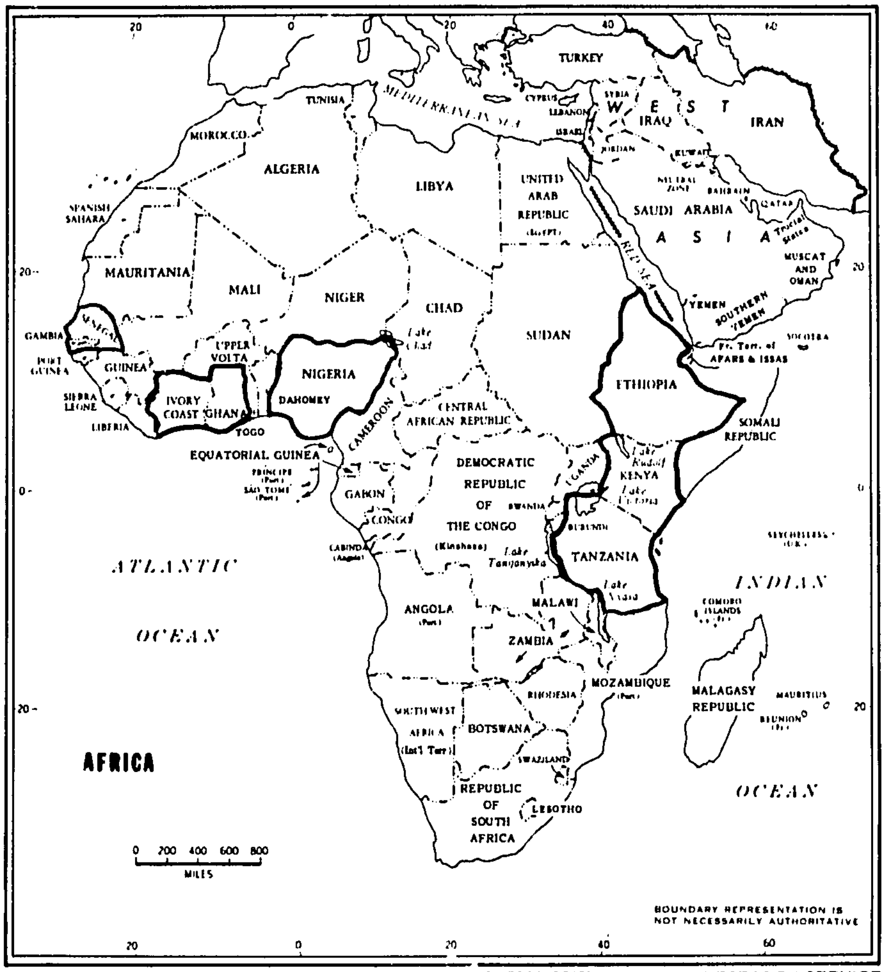

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Frontispiece: Map of Africa showing the countries included in the study of agricultural mechanization in Equatorial Africa. (Detailed maps for each country are shown in Figures 1.3, 1.4, 1.5, and 1.6 in Part Two, Chapter 1.)

KEY POINTS

Part One contains a summary of the findings of this study along with the Recommendations and Guidelines. The following Key Points have been extracted from the body of the report, Part Two, to present the authors' primary thoughts and observations as concisely as possible. Because the Key Points are taken out of context and tend to be somewhat fragmentary, most readers will want to refer to Part Two for a more complete discussion. To facilitate locating a particular Key Point, one will find them here by chapter and in the same order as in Part Two.

The reader should keep in mind that throughout this report the term *mechanization* includes hand tools, animal implements and engine power.

CHAPTER I
INTRODUCTION

- The significance of effective demand for agricultural produce in relation to programs of mechanization which increase agricultural productivity must not be overlooked.

- Where costs of clearing new land are rising rapidly the potential returns to using improved inputs in land already under cultivation must be weighed against potential returns to cleared new land.

- From selected cases of agricultural mechanization in Equatorial Africa, some generalizations of experience are possible to other areas with similar conditions. However, a much more reliable basis for planning the introduction of improved mechanized technology is to be found in the initial development of local adaptive research programs and pilot projects in the areas under consideration.

- The alternative to bush fallow is scientific management of all agricultural factors of production, beginning with scientific selection of soils.

- There is an urgent need for economic data which can form the basis for agricultural development planning. This necessitates the establishment of working procedures for record-keeping and the conscientious effort of all involved in these procedures.

- Comparative studies necessitate some standardization in record-keeping procedures between different countries.

- The small farmer (4-6 hectares) constitutes an extremely large proportion of African agriculture which must not be overlooked.

- At present, most comparisons between the relative merits of different levels of mechanization tend to be unhelpful because overhead costs and capital charges are not dealt with on comparable bases in estimating costs of different operations.

- Comparisons of operational costs are only helpful if related to returns to the same operation.

- There is generally a significant difference between the cost of hiring labor and the cost to a family farm of labor from the farmer and his

family. Imputed labor values vary within countries in different areas and between countries. These are differences which are important in making comparative studies.

CHAPTER II
GENERAL DESCRIPTION OF PRESENT FARMING SYSTEMS IN SELECTED EQUATORIAL AFRICAN COUNTRIES

- Ecological factors of climate and soils can act as principal limiting factors for increasing crop production.

- The cost of any mechanization program must be met out of the resultant increase in production.

- Encouragement to livestock production can help to foster the introduction of animal power into an area but in areas where the human population is very dense, cattle and humans are in competition for land.

- Evidence of land mobility can prove important in consolidating land for improved cultivation practices. Land fragmentation seriously limits possibilities for mechanization.

- In areas where there has developed a social system in which animal and crop husbandry are the principal occupations of different groups of people; these separate modes of living create special difficulties for the introduction of animal-powered technology.

- Hand-powered farming systems have developed an economic balance in which the people have confidence of the system's capacity to provide at least sufficient for survival.

- In agricultural systems which have already developed the market concepts of cash exchange and the production of surpluses for sale have already evolved many essential economic elements which will provide a basis for further development.

- Local economies which appear to be in a state of transition offer a fruitful area in which to establish extension services to disseminate information on new techniques and to distribute and demonstrate new tools, fertilizers and seed varieties.

- Local sentiment which tends to discourage employment of one type of animal should encourage endeavors to utilize other animals as agricultural power.

- The pragmatic approach to development attempts to solve problems which the local farmer identifies as relevant; to use unsophisticated techniques to demonstrate new cultivation principles; and to give instruction in terms and methods appreciated by local people.

- For the small farmer oxen offer certain important advantages over tractors, such as low running costs; easy management; multipurpose function, providing work and finally meat; minimal cash payments. The country is involved in minimal foreign exchange payments.

- The tractor comes into its own only if its operations can be spread over a fairly large area and be used for a major portion of the year. Tractor fixed costs are high in contrast with low oxen fixed costs.

- There is a reservoir of skills and individual enterprise lying in the private sector of a country's economy which should not be overlooked.

Commercially-based enterprise is obliged to retain a basic economic efficiency in the use of agricultural machinery in order to continue as a going concern. Government departments and commercial enterprises can work in cooperation in planning the introduction of more advanced forms of mechanization into selected areas.

- Pilot projects and experimental work are essential to settlement schemes and also to all development projects involving technology which is new to an area.

- Adequate extension assistance should be provided with new development programs.

- Changing from hand- to animal-, and animal- to engine-powered systems involves the farmer in a shift in cost structure from low to high production costs. This shift must be met by a comparable shift in income.

- Division of final responsibilities in the administration of tractor-hire services, or any other development program, can be expected to result in a faulty operation.

- The operation of large machinery services must be based on sound accounting and close attention to management.

- Subsidized services should be limited to areas which are economical to be developed from the point of view of the national economy.

- Small areas of crops cannot be cultivated efficiently by tractors.

- Mechanization is never to be regarded as an end in itself.

- Lack of adequate infrastructure can stifle economic expansion but, before new infrastructure is introduced into an area, the economic prosperity of the area should be assured.

CHAPTER III
ENGINEERING AND TECHNICAL ANALYSIS OF AGRICULTURAL PRODUCTION OPERATIONS

- In traditional farming, past improvement has come mainly from the farmer's increased manual skill in using traditional tools rather than from developing improved tools; future improvement will come primarily from the introduction or invention of more efficient tools and power systems.

- The use of improved seeds, fertilizers, irrigation and plant protection measures will not have the desired effect on production yields unless land is adequately prepared and cultivated in conjunction with improved cultivation practices.

- Ineffective hand tools waste energy, increase man-hours and are often responsible for low levels of production and negative attitudes detrimental to the development of a viable agriculture.

- With the introduction of specialized crops, development of export markets and utilization of animal and engine power, the differences in tools become more significant.

- In areas with distinct wet and dry periods, tillage time is very limited; the amount of land a family can farm depends on how much they can till by the optimum planting dates. Timeliness in completing the basic land preparation before planting is often very critical.

- Farmers who have used multi-purpose toolbars like them. Farmers would like to purchase multi-purpose toolbars if credit were available, and if implements were able to increase production efficiency enough to warrant the extra cost.

- Simple wood-bar flexible harrows or rigid-frame triangular harrows could be made locally in developing countries; they would be a welcome addition for secondary tillage on most animal-powered farms in Equatorial Africa which now have few tools of this type.

- Hand broadcasting is the most common method used by hand- and animal-powered farmers for sowing small grains in Equatorial Africa.

- The introduction of cash crops and improved practices, supported by marketing agencies and extension services, is gradually persuading hand-farmers to adopt row-planting.

- Furrows and ridges formed by hand-hoes and animal-drawn ridging plows facilitate row-farming practices.

- Seed is the only input of value that hand farmers and most animal-powered farmers purchase. Timing of planting always is regarded as critical for maximum yields. Good seed selection and proper cleaning is important, not only to secure good germination and growth characteristics, but to reduce weed competition and subsequent weeding costs.

- On non-irrigated upland soils timing of planting depends primarily on the rainfall pattern which is often unpredictable.

- Covering hand broadcast seed without help of additional animal- or engine-powered tools or harrows can be costly, especially if extra labor must be hired by the hand- or animal-powered farmer.

- For animal-powered farmers seed covering is usually a separate operation in the form of a plowing. The haphazard location of plants greatly hinders subsequent weeding operations by hand or animal power.

- In Tanzania the hand farmer can till, plant and care for only 1.2 hectares of cash crops plus another 1.2 hectares of food crops.

- In Ethiopia it takes an average of 23.3 hours to cover hand-broadcast seed with the plow and an additional 4 hours to sow it for a total of 27.3 man-hours and 46.6 ox-hours to seed one hectare.

- In Nigeria one-third of all new mixed-farmers (using animal power for the first time) failed after acquiring cattle and plows primarily due to the inability of the individual farmer to change his role from head of the family farm to 'manager' of the mixed farm.

- When soil conditions are favorable and the seedbed is properly prepared, labor-saving high capacity tools and implements can be used for inter-plant cultivation and weeding to expand the farmers' capacity to control plant environment on larger cropping areas.

- Weeding is considered the major constraint limiting cropping area that can be effectively cultivated by the small farmer.

- Both hand- and animal-powered farmers tend to let the weeds get too large before attempting to control them.

- High yield increases often can be obtained by slightly intensified weeding which more than pays the added cost of hired weeding.

- Until sufficient demand can be built up to warrant local manufacture, selected tools and implements should be imported and demonstrated to acquaint agricultural services and farmers with their capabilities.

- Flexible and semi-rigid tines are more expensive and draft-saving only at fairly high speeds and have no advantage with slow animal power over rigid tines fixed to a solid frame.

- By using a long (4.5 meter) hitch rope or chain, lateral movements of animal-drawn implements can be easily made to allow hoeing between plants in the row, which reduces hand labor to a minimum.

- The common African method of driving an ox team with two men, using whip and voice control, could be improved by using the European or Indian system using nose rings and lines controlled by one man.

- Weeding is the animal-powered farmers' most severe limitation. He must do a better job of seedbed preparation and preplanting weed control by using a more effective system of primary tillage. The indigenous plow should be improved or replaced.

- In Ethiopian fields prepared for planting by the indigenous plow, an average of over 220 weed plants were found per square meter.

- The ox-plow farmer must plant in rows properly spaced and aligned so that he can use more productive, time-saving, less expensive and more effective means of weed control.

- While chemical herbicides can control most weeds they are much too expensive now for the emerging farmer in Equatorial Africa in his present stage of development.

- Using a one-row animal hoe, a farmer can control weeds in one sixth the time required for hand weeding.

- Commercial firms are generally unwilling to sell, service and distribute improved tools unless there is sufficient demand from farmers and support from government advisory services.

- Even simple machines like hand-powered groundnut decorticators and threshers require special skills for adjustment.

- In Equatorial Africa, animal power is used for only one harvesting operation: lifting groundnuts.

- In eastern Africa, cattle hooves, but not implements, are used almost exclusively by animal-powered farmers to thresh small grains.

- There is a great shortage of animal-powered equipment available for harvesting and threshing crops in Equatorial Africa today.

- The best ox-drawn groundnut lifters reduce the hand labor requirement by half.

- Farmers complain that the new higher-yield varieties of wheat take from 40 to 60 percent longer to thresh than the native varieties.

- As new, higher-yielding varieties are introduced, more agricultural inputs are employed to intensify production, and cropping areas are expanded, the greater is the comparative advantage of mechanical power and machine-assisted methods.

- Potentially, one of the most important jobs for animals already possessed by farmers is hauling by carts and wagons. The cart has not been promoted successfully in Equatorial Africa.

- Where suitable wheeled carts are not yet obtainable, but adequate methods of yoking and harnessing of animals are available, much more use could be made of sleds as an inexpensive and practical substitute for wheeled transport.

- The proper lubrication of sleeve or anti-friction bearings is a critical problem in developing and maintaining animal-drawn carts. Since the average small farmer is unfamiliar with such problems he needs advice and training.

- The ownership of a simple farm cart involves considerable expense for the small farmer.

- There is a place for engine-powered agriculture in developing nations just as there is an obvious need for improved hand- and animal-powered farming systems.

- At the present stage of development, education level, dealer organization, accrued experience and expertise with machinery, estimates for length of service life of a tractor or implements must be greatly reduced, and the cost of repairs and maintenance increased for use in Equatorial Africa.

- No matter how simple or rugged a machine or tool may be, periodic attention is required for service and maintenance.

- Engine-powered cultivations can provide very good weed control when timely and well managed. The cultivator shovels cannot be worked close enough to the plants for effective weeding unless the rows are carefully marked with a furrow-marking device and seeds precisely planted by hand.

- In using motorized cultivators the quality of work depends largely on the operator's desire to produce good results.

- In using small tractors or rotary cultivators, good judgment and common sense are required to adapt the machine to special conditions and to obtain the best performance.

- The costs of operation will be substantially higher for a hire service catering to scattered farmers under typical African rural conditions of small fields, with irregular shapes and hidden obstacles, remote locations, restricted access, limited seasonal use and poor road conditions.

CHAPTER IV
ANALYSES OF PRESENT FARMING SYSTEMS

- The accelerated development of agriculture in Equatorial Africa cannot ignore the needs and the problems of the small farmer. He needs more power, improved tools and the benefits of technology along with support from local and national infrastructure. A market economy permits specialization, provides stimulus through profitable reward for the disposal of increased production.

- The size of family imposes definite limits on the area of land that can be cultivated by hand in any one year, and in determining the size of holdings per family.

- If preparation time is limited or soil condition is very difficult, large

amounts of hand labor must be available to quickly prepare land for planting. This labor peak determines how much land a farmer can handle though there may be surplus labor the rest of the year.

- Hand winnowing in the wind often takes more time and presents more difficulties than the actual threshing.

- Improved storage facilities are needed by nearly all farmers so they will not be forced to sell at harvest time and enable them to raise more for commercial sales.

- Far from diminishing, animal-draft is likely to remain a major source of power for the emerging Africa farmer for the remainder of this century.

- Wherever used, increased power must be applied through improved implements in the hands of more efficient farmers before benefiting agricultural productivity.

- Whatever the scale or level of agriculture, the farmer is a tool user.

- While engine-powered machinery may be employed successfully in some areas of each country, wherever applicable, improved types of animal-powered farm implements are needed to facilitate better farming practices such as controlled placement of fertilizer, row-planting and rapid, effective weeding.

- In Ethiopia, farmers on the average use their oxen about 30 percent of the working days and to 70 percent of capacity during peak work periods.

- Farmers in developing countries are interested in changing their present farming methods. In the area of south central Ethiopia where Chilalo Agricultural Development Unit of the Swedish International Development Agency is located, nearly all traditional subsistence farmers believe they could increase the output from their farms with better plows, better seeds, fertilizers, and more frequent weeding.

- In Ghana it is estimated that to justify owning oxen for farm power, a farmer should have 4-6 hectares of crop land, 70 days of tillage work and 120 days of cart work per year for each pair of oxen.

- In planning mixed farms in Nigeria and equipping them with ox power, the agricultural officials have established a minimum farm size of 8 contiguous hectares.

- In Tanzania the major effect of changing from hand cultivation to ox cultivation was to transfer the labor peak from primary cultivation to weeding.

- Improved plows and more power for effective tillage and weed control should be matched with greater emphasis on soil and water conservation measures.

- In areas with hard dry soils which must be softened by rains, the major limitation is primary tillage for the hand farmer and weeding for the animal farmer.

- In animal-powered farming areas such as Ethiopia, there is a need for some type of spring-tooth or spike-tooth harrow for leveling land prior to planting, for covering seed to a uniform depth and for reducing the work of covering seed.

- To overcome the difficulties and slowness of winnowing in the wind, a simple hand or foot operated winnowing fan or fanning mill is needed to quickly and efficiently remove weed seeds and foreign material.

- For planting row crops a simple inexpensive animal-drawn seed planter is needed to sow a variety of seeds at desired rates with reasonable precision.

- In most developing countries the demand for animal carts greatly exceeds the supply of used wheel and axle assemblies; special wheels, axle and bearings with spare parts will have to be imported to meet the rising demand.

- The wise selection, rational use, full utilization, proper care and maintenance of suitable machinery will make any good farmer a better farmer.

- The coordinated implement and power system can add to the system by doing a better job, by doing it more timely, by enlarging the scope of operation, by making it possible to carry out some improved practice, by preventing loss or destruction, by improving management, by combining operations, and by controlling factors that limit production.

- One of the major factors influencing high cost is the underutilization of expensive machines and power units through idleness or non-productive operations.

- In developing countries, more emphasis must be put on multiple-cropping and on diversification of operational tasks to fully utilize productive machinery.

- Increased field efficiency can be obtained by recognizing the importance of the tractor operator and his need for training, recognition, and experience.

- The use of more than one driver for each machine tends to absolve responsibility for the machine.

- In the operation of government tractor-hire services, the problems of organization and logistics in smallholder areas makes economic operation extremely difficult.

- Experience has shown that it would be difficult to achieve 70 percent field efficiency while working small holdings.

- In the operation of a tractor-hire service in undeveloped areas, the construction of farm access roads should receive top priority and be a prerequisite to opening new schemes.

- The government should encourage private and cooperative contractors whether they are subsidized or not, by using their services whenever possible and by refraining from competition during formative years.

- Many of the problems in operating a central machinery pool have roots in established government procedures: difficulty of flexibly altering rules to meet seasonal or long term needs; lack of mobility resulting from housing policies and payment of travel allowances; need to protect public funds by complex store and accounting procedures and the difficulty of paying incentive bonuses for increased productivity.

- Where mechanization is introduced, justification and evaluation should be based on factors other than yield, *e.g.*, timeliness of operation, weed control, control of erosion, suitability of machines, ease of harvest, freeing the farmer for other productive work, and need not be the same for each crop.

- Small utility tractors are not inexpensive but conditions have improved in the last decade so that much greater value can be obtained.

- Whether the basis of comparison is price per usable horsepower or capital required per hectare, the small agricultural tractor is usually more expensive than the larger tractor when it is adequately sold and serviced by a dealer.

- While small single-axle rotary hoes or cultivators are functionally practical, they cannot be recommended for general adoption and use without operator training and good supporting services.

- Improvement in mechanization takes the form of either changing an existing system, or introducing a new system; but whichever approach is adopted, the form of mechanization must be appropriate to the agricultural environment.

- A more sophisticated form of power need not be associated with a more advanced level of economic development; the optimum level of economic development is achieved by maximizing returns from a given set of resources.

- Economic systems in which cash exchange and the concepts of commercialization already exist contain important features which will greatly facilitate further development.

- An area of social and economic transition contains certain elements, especially with respect to flexible personal attitudes which facilitate economic development.

- Cultivable land can be limited in areas of village settlement by practical walking distances, even though there appears to be an abundance of land.

- Credit facilities are an obvious need throughout Equatorial Africa; however, their establishment can lead to chronic indebtedness unless suitable repayment facilities are also included in the program.

- The competence of a local extension service is extremely important to any development area with a generally low level of education.

- Economic infrastructure must be expanded to accommodate development programs; without adequate infrastructure, improved mechanization or any other scheme will be stifled.

- Local experimentation is extremely important in the development of new techniques suitable for a particular locality.

- Large-scale engine-powered operations provide a training facility for indigenous enterpreneurs.

- Large-scale engine-powered operations can provide a substantial cash boost to local small-scale economies by employing much hand labor; in this way the monetary economy can be expanded.

- Large-scale enterprises have command over sufficient resources to play an important role in the early stages of developing a new area.

- Mechanization can expand production substantially beyond the effective demand of local markets; exporting onto the world market is not easy for new producers of a commodity because of well-established standards of quality and trade procedures.

- The scope for mechanization in areas of mixed-crop (inter-crop) practices appears limited to improving hand tools; generally more sophisticated mechanization requires single crop cultivation.

.... organization must be sufficiently flexible, through amalgamation and consolidation of fragments, to facilitate the use of improved animal- and/or engine-powered technology.

- Total annual costs of production for small farmers using oxen power are maintained at a low level, relative to tractor power; however, these relatively low costs are generally accompanied by lower productivity.

- In areas where antipathy exists between different groups of villagers, commercial enterprises cannot assume that local hand labor can be hired easily since different village groups may not be willing to work together.

- Extension service demonstrations on model farms fail to be useful in areas where local farmers are antipathetic toward their more successful neighbors.

- A shift from less to more sophisticated levels of mechanization is accompanied by a concomitant employment shift from simple to more complex skills.

- The introduction of improved tools and agricultural machinery should always be planned in the context of an overall plan for economic development. The precedence of family loyalties should be taken into account in such plans since personal attitudes strongly influence the way in which individuals cooperate with planners.

CHAPTER V
INTRODUCTION OF IMPROVED TECHNOLOGY AND POWER INTO PRESENT FARMING SYSTEMS

- Agricultural productivity can be increased most rapidly by concentrating on a limited region and a selected number of people. Farmers most likely to adopt a decisive package of inputs leading to increased returns are those who have had some successful experience and have more than the average amount of resources to risk on new innovations.

- In developing countries agriculture in its entirety, from the farmer to the Minister of Agriculture, is confronted with the need to develop an attitude of experimentation, continued innovation, and adaptation of new ideas.

- The optimum package of inputs makes maximum use of on-site available resources and provides the best compromise between potential results and the likelihood of successful promotion and effective adoption of improved practices and tool systems.

- Sustained growth in agriculture depends on the creation and implementation of a broad-based research and educational system responsive to the needs of rural society.

- A system for popularizing the results of research is essential so that the research can ultimately lead to the transformation of the working habits of farmers.

- Progress should be obtainable by most farmers without making investments or effort out of proportion to the anticipated increased return.

- Ox power is especially suited to tropical areas of high elevation with temperate climates and 76 to 100 cm. of rainfall per year.

- To be served by Motoragri, a government mechanization organization in Ivory Coast, small farmers with less than 5 hectares must form contiguous groups

of at least 20 farms so that a minimum of 100 hectares may be worked in one area.

- The Narosurra Farm Mechanization Training Scheme in Kenya teaches young African farmers to become tractor operators and better managers in three months of intensive, practical and enthusiastic training.

- There must be adequate incentives available to any system to encourage a higher level of production before attempting to introduce new levels of mechanized technology.

- Programs of development should be integrated into national policy. The benefits from programs to improve agricultural mechanization can be increased by retaining inferior produce on the domestic market and exporting superior produce onto the world market.

- The appropriateness of a mechanization program is closely related to the level of management achievable by local farmers (assisted by extension agents, if necessary).

- Roads, railways, bridges, schools, repair and maintenance services, credit and banking facilities are all aspects of local infrastructure having a fundamental impact on developing an area's economic potential.

- Smallness of operation is a serious constraint to the scope for mechanization.

- In hand-, and often animal-powered systems, size of operation is frequently too small and returns are subject to too high risk to permit experimentation; innovation at these levels of mechanization is usually carried out by external agents.

- An economic conflict arises in the development of engine-powered technology. Complete mechanization of the productive process realizes substantial economies, but partial mechanization can generate substantial employment, thereby diluting some potential economies of mechanization.

- Positive planning is necessary to establish a large-scale operation as a local economic stimulus; otherwise, indigenous agriculture and large-scale farming coexist, each having little impact on the other.

- The introduction of new implements into areas with inexperienced users should be accompanied by practical training courses. These courses should always be in terms which are relevant and familiar to the local situation.

- Effective demand requires effective articulation between producer and consumer, and a functional medium of exchange; hence, lack of monetization limits technological development.

- Mechanization is only one factor in combination with many others. The priority given to mechanization to develop different systems is frequently not of the first order.

FOREWORD

The term mechanization, as used by the authors throughout this study encompasses the use of hand and animal operated tools and implements, as well as motorized equipment, to reduce human effort, improve the time lines and quality of various farm operations, thereby increasing yields, quality of product, and overall efficiency.

The Study, sponsored by the United States Agency for International Development under Contract AID/afr-459, was conducted from February 1, 1967 to December 31, 1969, by a four man study team from Michigan State University.

Primary attention was focused on Ethiopia and Ghana with travel to Gambia, Ivory Coast, Kenya, Nigeria, Senegal and Tanzania to study specific projects and confer with individuals (see map: *Frontispiece*).

To describe the broad geographic area of Africa covered, the term Equatorial[1] has been selected. Although there is no common agreement among scientists regarding the elevation ranges within the Equatorial Belt that are considered "Tropical", several criteria have been advanced. These include:

1. Areas free of frosts.
2. Areas with climates favorable to production of cold-sensitive perennial crops such as sugarcane, banana, and coconut.
3. Areas too low in elevation for production of wheat.

Following are the percentages of land at the respective ranges is elevation.[2]

PERCENTAGE OF EQUATORIAL AFRICA WITHIN RESPECTIVE RANGES OF ELEVATION

Range in Elevation	Area of Equatorial Africa
meters	percent
1,836 to 3,672	3.0
918 to 1,836	24.0
306 to 918	54.0
0 to 306	19.0
Total	100.0

At the Equator the elevation point that divides Tropical from Subtropical ecological conditions is approximately 1,530 meters; near the Tropic of Cancer

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[1]Equatorial Africa is generally considered to be the Torrid Zone, lying astride the Equator from the Tropic of Cancer (23° 27' North Latitude) to the Tropic of Capricorn (23° 27' South Latitude).

[2]Based upon estimates made by counting squares on a plastic grid from the "Land Features Map", *World Atlas*, (Chicago: Encyclopaedia Briticannica Inc., 1964), pp. 146-7.

and the Tropic of Capricorn the dividing point is approximately 1,071 meters. Each 1^{o} departure in latitude, north or south, from the Equator therefore would be equivalent ecologically to a decrease in elevation of 20 meters. Other modifying factors are air temperature, proximity of ocean currents, and temperature of the prevailing winds.

According to the above table, Tropical Equatorial Africa therefore would include the areas within 0-306 meters, 306-918 meters, and about half of the areas within the 918-1,836 meter range in elevation. Thus, of Equatorial Africa, 85 percent, or about 19.4 million square kilometers can be considered Tropical, and 15 percent or about 3.4 million square kilometers as Subtropical.

The Study had been conceived as documented compilation of published and unpublished data on mechanized farming and related topics, to identify engineering problems and make recommendations for future planning. In general this policy has been followed but, in a few cases, the absence of secondary data forced the Team to collect its own information. To coordinate the large number of data sources, units have been converted to the metric system and monetary values to U.S. dollars.

The Study Team hopes that the information compiled will prove of value in planning and implementing mechanization programs. The recommendations, both general and specific, are aimed at improving the productivity of Equatorial African agriculture through selective mechanization.

Several different audiences are envisaged for this report. Individuals at the policy-making level will be interested primarily in Part One which contains the Summary and Recommendations. Specialists, scholars and others interested in particular aspects of mechanized farming in Equatorial Africa will find details in Part Two. The bibliography, in Part Three, lists over 400 annotated references. Photographs have been used liberally to provide clear descriptions of farming conditions and the diversity of tools and machines currently used.

Such a broad study involving travel and consultations in eight countries of Equatorial Africa, prevents the Study Team from adequately crediting all the people who so kindly helped.

Thanks are due the advisory group, comprising: Dr. William Chancellor, Professor, Agricultural Engineering Department, University of California, Davis, California; A.D. Faunce, former Chief, Agricultural Engineering Branch, Land and Water Development Division, Food and Agriculture Organization (FAO), Rome, Italy; N.M. Garrard, Overseas Liaison Officer, National Institute of Agricultural Engineering, Silsoe, England; Lloyd Johnson, Agricultural Engineer, Rockefeller Foundation, formerly with the International Rice Research Institute, Manila, Philippines; G. LaBrousse, Chief, Agricultural Engineering Liaison Office, Research Institute for Tropical Agriculture, (CEEMAT), Antony, France,

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A DOCUMENTARY FIELD STUDY

PART THREE

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AGRICULTURAL MECHANIZATION IN

EQUATORIAL AFRICA

PART ONE

SUMMARY, RECOMMENDATIONS AND GUIDELINES

PART ONE

PREFACE

Part One consists of a summary, recommendations and guidelines.

Each numbered section in the Summary relates directly to the corresponding chapter in Part Two which is the body of the report and contains the data, analyses and illustrations.

Twelve recommendations are presented covering a broad range of activities and programs which the authors feel are essential for effective use of various levels of mechanization in agriculture. The recommendations stem from the total experience of the Study team which includes many years of work in developing countries prior to this project. The Recommendations have been stated as briefly as possible. They are intended to deal with principles and broad concepts rather than specific details for implementation which will vary for every location.

Some suggestions for implementation of the Recommendations are presented as guidelines. Each related Guideline is numbered to correspond to a Recommendation. The Guidelines will have to be adapted to each local situation, but it is intended that the Recommendations will be valid at the appropriate local, national, or international level in the countries within the Study area.

SUMMARY

Introduction

The Nature of a Mechanization Study

African economies are primarily agricultural and the key to economic development for nations in Equatorial Africa lies in raising the productivity of the agricultural population. In order that increased agricultural productivity may realize increased income for farmers the general prosperity of nations must be stimulated to increase effective demand for agricultural produce. Agricultural production may be raised by either bringing more land under cultivation or by increasing the productivity of land already under cultivation. Mechanization is an important input which facilitates increasing agricultural productivity, but it is impracticable unless there is also means for profitably disposing of the resultant increase through commercial outlets. Thus, the mechanization of agriculture and the development of a commercial economy are concomitant factors in programs of economic development.

There is a shortage of farm power in Equatorial Africa, over 99 percent being derived from human effort. A human being has been rated at about 1/10 horsepower, while the minimum power requirement for an efficient agriculture has been estimated at about 1/2 horsepower per hectare.

The definition of agricultural mechanization employed in this Study is: any mechanical means used in the processes of agricultural production. This definition includes hand-, animal-, and engine-powered equipment in the contexts of production, processing, transportation and marketing of agricultural produce.

In each case, from the simplest hoe to the most complicated machine and powerful tractor, the purpose of mechanization is to make man a more efficient director of power. When a farmer acts as both a producer and director of power his activities as a director are greatly limited since most of his energy is used in meeting the demand for power. Power is time-rated, so the farmer's total capacity to work the land is dependent primarily upon how many able bodies can be employed during the time period for key operations. Bottlenecks develop because soil preparation, planting, weeding, and harvesting require much time. It should be recognized that most farmers in Africa, particularly those in the savannah areas, consider labor their principal constraint (despite apparent underemployment for most of the year) and are primarily interested in maximizing their returns to labor rather than to land.[1]

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[1]John C. de Wilde, "Making Agricultural Research Relevant to African Farmers," *Conference on Agricultural Research Priorities for Economic Development in Africa*, Vol. III: *Contributed Papers: Animal Production and Health, Economies; Farming Systems; Education; Research and Institutions* (Abidjan, Ivory Coast: National Academy of Sciences, National Research Council, 5-12 April, 1968), p. 177.

The Fundamental Importance of Soil and Crop Management

While mechanization is an essential factor for increasing agricultural productivity, its success is preconditioned by basic factors of management of favorable soils and crops. The adoption of new forms of power can lead to increased production due to both higher yields and greater area in crops.

Scientific soil and crop management began late in Africa. Marbut has expressed a strong opinion that soil and land use surveys should be the scientific basis of land use.[2] Potential crop yields of the tropics in general tend to be higher than those in temperate zones and, where soils have been well used, fertilizers can rapidly rejuvenate. Soil survey work will assist in future use of soils, and the appropriate form of mechanization to be applied in their cultivation.

Bush fallow or shifting cultivation traditionally has been followed over much of Equatorial Africa. For a subsistence agriculture with low inputs and outputs no more satisfactory technique has evolved. The bush fallow system, however, can be practiced only in areas of low population density. The alternative is scientific management of all factors of production, starting with the selection of soils that are most responsive, managing them scientifically and using modern inputs. Such an approach demands scientific field research, an area of inquiry in which much work remains to be initiated.

Traditional farming systems appear similar throughout Equatorial Africa except in the highlands of Ethiopia, Kenya, and Tanzania. Small garden cultivation produces vegetable and tree food crops continuously by using animal manures; bush clearings are cultivated for 2 or 3 years and then abandoned to fallow for 15 to 20 years.

Population pressure gradually demands a scientific approach to soil management and the question arises of a satisfactory alternative to shifting cultivation. Scientific soil investigators also must determine how soil structure can be maintained and erosion controlled, the most economical use of fertilizers on tropical soils, and cultivation techniques to avoid laterite hardening.

Overgrazing, wind and rain erosion are important ecological factors to consider in scientific soil management. Where population is sparse in the savannah belt only 5 to 10 percent of land is in cultivated crops each year. However, in areas of heavy rural population pressure where land is needed and cannot be left in fallow an average of 6 out of 8 years, and in the rain forest areas cleared for large scale mechanized farming, soil erosion is probably the most serious of all problems in soil management. For instance, southeastern

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[2] A.L. Shautz, and G.F. Marbut, *Vegetation and Soils of Africa* (American Geographical Society, 1923).

Nigeria's problem of erosion stems from great population pressure and high rainfall.

General Background to Mechanization

In terms of engine-powered mechanization Kenya has more agricultural tractors than any other country included in the Study (6,145 in 1966). The order for nine countries in 1964-5 was: Kenya, Tanzania, Ghana, Uganda, Ivory Coast, Ethiopia, Nigeria, Senegal, and Gambia.

Data on the relative proportions spent on tractors and agricultural machinery for the period 1960-1967 show:

Ethiopia Total purchases of agricultural machinery have increased, but the relative proportion of tractors included in these imports has decreased; there has been a substantial increase in the importation of tractors relative to the number in the country;

Gambia There has been a slight decline in agricultural machinery imports relative to total imports; the number of tractors imported has declined both in proportion to numbers in the country and in proportion to other agricultural machinery;

Ghana Although fluctuating, the proportion of total agricultural imports tends to be constant; tractor proportions substantially increased, with a large boost in tractor imports in 1961;

Ivory Coast The relative value of agricultural machinery to other imports has remained fairly constant;

Kenya Agricultural machinery imports have gradually increased in relation to total imports; there has been a gradual increase in both the proportion of tractors in the imports of agricultural machinery and in the relation to total numbers of tractors in the country;

Nigeria The relative proportions of both agricultural machinery and tractor imports have remained at a fairly constant low level of total imports; tractor imports have ranged from about one-half to two-thirds of the total value of agricultural machinery imports;

Senegal The relative proportion of agricultural machinery imports to total imports has remained fairly constant at a low level; there has been a substantial increase in the relative proportion of tractors in agricultural machinery imports;

Tanzania Agricultural machinery imports have remained a fairly constant proportion of total imports; tractor proportions of agricultural imports have increased;

Uganda Agricultural machinery has remained a fairly low percentage of total imports, tending to decline slightly; tractor imports have been a substantial proportion of total agricultural machinery imports.

An examination of the operational costs for tractors and various agricultural processes in the countries covered by the Study reveals a wide variation in the composition of these costs. It is clear that low operational hours and high administrative and transport costs militate against the economical use of engine-powered agricultural machinery.

Comparative costs of operating hand-powered tools, oxen-powered equipment, small engine-powered equipment and tractor-powered equipment in comparable cultivation practices suggest that costs are highest per hectare for operating oxen and lowest for tractor operations. These data are taken from specific experimental work in northern Nigeria and should not be used to draw general conclusions without making similar economic investigations in other areas. Although such studies have not been correlated with levels of production it is evident that the speed and capacity of tractor operations is responsible for low costs per hectare. Tractor operation is charged only for depreciation and maintainance over the time of operation; in contrast, the oxen farmer's depreciation costs are small, but must be met for the entire life of animals and equipment. Thus, such studies do not permit an accurate comparison between different levels of mechanization, nor do they take into account the very large capital outlay required for engine-powered equipment. A further problem with comparative costs of this nature is the low opportunity costs for the self-employed farmer; if there is no alternative employment for the hand labor of the farmer, then an imputed value for hand labor is unrealistic since the operational costs for hand cultivation tend to approach zero.

Mechanization and Its Role in Agricultural Development

The cornerstone for economic progress of any nation is the development of its natural resources and manpower. The developing nations of Equatorial Africa are richly endowed. Equatorial Africa has the largest amount of arable land with year-round growing potential of any continent: 724 million hectares of potential arable land, of which over 90 percent lies in the tropical belt.[3]

Potential for Multiple Cropping in Equatorial Africa

The potential arable land is especially significant because it lies in climatic zones which allow 2, 3 and even 4 crops to be raised annually. Thus, the African nations could become an important supplier of food and fiber to the world if the main limitations of water and power can be overcome and the necessary human resources supplied. At the present time,

[3] President's Science Advisory Committee, *The World Food Problem* (Washington, D.C., U.S. Government Printing Office, May, 1967), Vol. II, p. 431.

however, Africa has the largest area under shifting cultivation of any continent. The Chinese Rice Production Teams show conclusively that yields of rice comparable to those obtained in Taiwan can be produced in many African countries by using the same varieties of rice and similar cultivation practices.

In the Yamoussoukro Valley in the Ivory Coast, an irrigated rice project was observed which produced 7,000 to 8,000 kilograms per hectare per crop. But the outstanding feature was the production of 3 crops per year for a total average yield of 21,000 to 24,000 kilograms per hectare per year. Further, the International Rice Research Institute (IRRI) has produced newer varieties which have out-yielded all older varieties (including those used in Taiwan and the Ivory Coast mentioned above) by 1,000 to 2,000 kilograms per hectare. Thus, the tremendous potential for Equatorial Africa is demonstrated.[4] Raising three crops per year, however, requires additional power and improved tools. A major objective of this Study is to consider how these requirements can be met.

Intensified Annual Production

Agriculturalists must "think in terms of production for as many days of the year as possible."[5] The objective of modern agriculture is to produce as much food and feed per hectare as is economically feasible and to give the smaller farmers, with only 2 to 10 hectares, a better income and a far higher standard of living. Another objective of IRRI has been to minimize and mechanize the many operations involved in crop production.

> Our experience to date indicated that much of the hand labor in use on small farms can be replaced by suitably designed machines. Labor thus freed can be absorbed at more productive jobs . . . The inputs for such systems are: high-grade varieties of all crops, water control at all times, with plenty for irrigation during the dry season and ample provision for drainage during the wet season. Fertilizers under these conditions can and must be used liberally. Insect pests, crop diseases and weeds must be controlled at all times. . . Unit costs of production can be lowered because of the higher yields and the more efficient use of land, labor and equipment.[6]

Increasing agricultural production is a feasible proposition only if the economy is able to absorb the additional output. Equatorial Africa is faced

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[4] Richard Bradfield, Consultant in Agriculture, Rockefeller Foundation, International Rice Research Institute, Manila, Philippines, *Farming Systems in Africa: Management of Crops, Soils and Water, Mechanization* (paper presented at Conference on Agricultural Research Priorities for Economic Development in Africa, April, 1968), p. 5.

[5] *Ibid.*, p. 9.

[6] *Ibid.*

by a serious deficit in effective demand. The terms of reference for a mechanization study are such that investigations are directed mainly at agricultural production processes but the significance of effective demand must not be overlooked. Without a reliable outlet to absorb increases in production, which are essential concomitants to agricultural mechanization, every mechanization scheme will quickly flounder and become an embarrassment to its sponsors.

Diffusion of Technical Knowledge

The essential problems of technological improvement are to supply knowledge to the small farmer and to make available the necessary inputs to facilitate his becoming a more productive farmer .

> To persuade farmers to accept the techniques and methods of modern agriculture is a formidable and complex undertaking. Farmers in traditional subsistence economies are understandably wary of assuming new risks because they are so close to the margin of survival. If a farmer is to invest in the modern inputs of improved seeds, tools, fertilizer, and pesticides that are essential to increasing the output of his land, these resources must be easily available to him, a system of farm credit must be established so that he can afford to purchase them, he must be instructed in the proper and economic utilization of these materials, he must be reassured that he will be compensated for possible losses incurred in the process of innovation, and, above all, he must be shown that the potential payoff is worth the risk. Land tenure policies should not be such that his landlord will profit and he will not . . . pricing policies should not favor the consumer at the expense of the producer.[7]

The Small Farmer as Decision-maker

The outcome of all attempts to diffuse technical knowledge depends on how the small farmer employs his resources. If effective changes are to be introduced into traditional agriculture to encourage the emergence of a commercial system, the small farmer must be completely incorporated since it is he who is responsible for production.

The small farmer can be by-passed in certain commercial-type operations producing sugar cane, sisal, cotton and palm oil. Such products are generally export or import substitute crops. This usually occurs when special knowledge, extensive capital, and large-scale operations are used to produce these commodities. However, the small farmer may become an important contributor to these industries since they offer him a ready market for production beyond his family needs if he is able to meet minimum technological requirements. To produce beyond his immediate family needs the small farmer must be able to improve his allocation of resources at all levels of production. The economic use of additional mechanical power will facilitate this process.

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[7] President's Science Advisory Committee, *The World Food Problem*, Vol. II, pp. 15-16.

Objectives of the Study

The objectives are as follows:

1. To identify and analyze farming methods now followed and the types of tools and equipment now used;

2. To identify the factors or conditions favoring or hindering various forms of mechanization;

3. To make an economic appraisal of the problems inherent in selective mechanization in the areas studied;

4. To identify specific agricultural engineering problems requiring attention and suggest related research; and

5. To develop a series of generalizations as the basis for planning selective mechanization programs.

Methodology

The members of the Study team were involved in African field work for approximately eighteen months. First-hand experience was gained by personal observations of programs and schemes related to agricultural mechanization in Equatorial Africa, and by interviews with professional persons involved in these operations. Two countries were selected for study in depth: Ethiopia in eastern Africa, and Ghana in western Africa.

The approach to agricultural mechanization has been to envisage the agricultural system within which power and implement systems are one of many inputs in the production function. This approach necessitates the description and analysis of a number of representative cases.

General Description of Present Farming Systems in Selected Equatorial African Countries

The process of agricultural mechanization involves changes in agricultural technology. In terms of basic factors of production, the agricultural production function combines land, labor, and capital in a manner supervised by the farmer acting in his role as manager. Increasing the power element in the production function is achieved by any increments of capital, substituting either for labor or land, or being a neutral technological change. The change which agricultural mechanization effects is summarized in the consequent change occurring in the production function.

Three broad categories exist in farming systems. Because contemporary systems are dynamic it is difficult to maintain a strict division between hand-powered, animal-powered and engine-powered agriculture.

Ecological Factors

In agricultural systems the most important ecological factors are soil and rainfall. To illustrate data necessary for a scientific approach to agricultural mechanization, soil analyses were conducted at five Ethiopian study sites. Table I summarizes the soil and rainfall characteristics for Ethiopia.

TABLE I AVERAGE RAINFALL, ELEVATION, AND DOMINANT SOILS AT FIVE ETHIOPIAN STUDY SITES

Study Site	Average Annual Rainfall (millimeters)	Elevation (meters)	Dominant Soils
Agnale Village (Pokwo)	900 to 1,000	1,800	Silty and clayey alluvium from Baro River
Chilalo Agricultural Development Unit (CADU)	700 to 1,000	2,000 to 2,500	Dark brown clay developed from calcareous lava and bedrock; some red, acid clays
Amibara (Middle Awash Settlement Scheme)	350 to 450	750	Silt loams and clay loam alluvium from Awash River
Tendaho (Tendaho Plantations Share Company)	100	400	Silty and clayey alluvium from Awash River, some saline
Setit-Humera	500 to 700	500 to 700	Vertisols (deep, black residial clays)

Hand-powered Agriculture

Technical and Engineering Factors

Throughout Equatorial Africa the typical farmer is a hand tool user. At no place in Equatorial Africa does any form of power farming, either animal or engine, exist without some use of hand tools. While a great variety of hand tools exists, there is a remarkable similarity in tools among countries and regions. Because of the arduous nature of hand work, especially in primary tillage, the hand farmer favors the concept of minimum tillage. Where there are distinct dry and wet seasons with hard soils, intense rainfall and critical planting times, the farmer has to compromise to get his crops in on time and to plant a sufficient amount to feed his family. As a result of the severe limitations and his inability to control nature, he has evolved rather strict systems of cultivation practices which assure him a food supply with the least risk of failure.

1) Mixed Cropping

One widely practiced system of hedging against risk is mixed cropping; common in western Africa, with 2 to 8 different crops grown together on the

same plot of land. Mixed cropping can be practiced in both shifting cultivation and permanent agriculture. Several advantages to this system of cropping are: (1) assurance against crop failure since it is unlikely that disease, drought or insects will wipe out all crops; (2) higher total production from several crops than for individual crops grown singly;[8] (3) more efficient use of available power since the ground needs to be prepared only once for several crops; (4) concentration of crops permits selection of the most suitable land for cultivation; (5) weed control promoted by close spacing and intensive hand cultivation; (6) observation of all crops; (7) period and uniformity of labor utilization extended by continuous planting, weeding, harvesting, tilling and replanting; (8) a longer fallow period permitted for renewing the land and controlling severe weed problems.

Mixed cropping also has definite drawbacks which inhibit the introduction and adoption of improved agricultural practices and tools. Some disadvantages are: (1) it is not possible to use efficient weeding methods or tools in randomly-spaced crops; (2) work is more tiring and less efficient when it is difficult to distinguish between mixed crops and weeds; (3) fertilizer cannot be tailored to individual crop needs; (4) spraying for specific insects and diseases is impossible; (5) the system discourages specialization and research to improve crop production.

2) Hand Tools

The tools of the hand farmer are made generally by local artisans; they are inexpensive and easy to repair. Farmers who seldom know about anything better, are satisfied and make up for deficiencies in design and materials by increasing human efforts or by improving dexterity. Most tools are made out of scrap metal; rural blacksmiths seldom know how to temper metal so that it will keep a true, sharp edge. Tools soon become dull, are seldom sharpened, and farmers continue to use them until they are worn beyond efficient use.

Considerable improvements can be made in present designs if metal parts are made of properly tempered high-carbon steel which lasts longer and holds a cutting edge. Design improvement for all tools should consider balance, manipulation and weight. Tools which effectively utilize man's strength, without being too heavy or causing undue fatigue, would be a marked advance toward greater efficiency.

The best tool, however, must be available locally. Supply and distribution of simple improved tools at the village level in developing countries

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[8] C.J.N. Gibbs, *An Economic Study of Three Villages in Bauchi Province*, Samaru Miscellaneous Paper (draft) (Samaru: Ahmado Bello University, Institute for Agricultural Research, Rural Economy Research Unit, August, 1968), pp. 18-19.

is a critical problem. More effort and motivation is required to improve the supply of improved tools in villages distant from main roads. Tool parts are heavy, profit margins are small, and the average trader is reluctant to handle new items not yet accepted, even though they may be technically better than traditional tools.

In all probability the most effective and lowest cost distribution can be obtained by establishing small factories in each country. In most African countries, as pointed out by de Paul of Scovil Hoe Company of the United States, the right kind of tool-steel must be imported since this is the heart of the tool.[9] Steel blanks can be prepared and sent in bulk at very reasonable cost to small finishing plants in Africa for final processing. But, even if this is done, there is still the problem of getting the tools into the hands of farmers and encouraging them to use it. Since the local blacksmith is the source of community repairs and the supply of indigenous tools, he should be given practical training to increase his capabilities.

Hand-powered Agriculture

Three cases have been selected to exemplify the hand-powered agricultural system: Agnale Village, southwest Ethiopia; Zuarungu District, northeast Ghana; Nasarawa Village, northern Nigeria. Hand-powered economies are complex farming systems because each unit is organized to be self-sufficient. In the more sophisticated cases of Ghana and Nigeria, a large variety of crops are grown in mixed cropping system to insure against the risks of crop failure.

1) Agnale Village, Ethiopia

Agnale village represents the least sophisticated hand-powered system. Main crops are maize (corn) and sorghum. Land is relatively abundant (the village farms about 38 hectares) and crop yields from 2 crops per year are adequate for the population. There is little privation in the area except for a short "hunger time" immediately before the July-August harvest period. The agricultural system is in balance with a reasonable distribution of leisure time throughout the year. This case demonstrates the labor constraint on expanding any productive possibilities. During the January-March period, labor requirements reach the maximum which the work force of the village can supply. Also, the system lacks any market infrastructure and is completely non-monetized. The economy has no facility for absorbing surplus production which the least sophisticated form of mechanization can realize.

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[9] N.C. de Paul, Scovil Hoe Company, Division of Somoa Corporation, Higganum, Connecticut, Personal Communication, November, 1968.

2) Zuarungu District, Ghana

Zuarungu district is a heavily populated area of northeastern Ghana in which a shortage of cultivated food is a common experience. The area had no activities other than hand-powered farming before World War II. Since then, the town of Bolgatanga has developed as a commercial center and a few commercial enterprises have been established. Agriculture is fixed in a pattern of small homestead compounds with farms averaging 3.23 hectares. Mixed cropping is the general rule for a wide variety of crops, and some livestock are owned, but poorly cared for, by the average farmer. Zuarungu district represents a system with an underutilization of available labor and a general lack of power to improve the quality of tillage practices. Additional power could be obtained by diversifying into a mixed-farm system employing animal power and selling animal products. An adequate potential market exists to support this development but the farm structure at present is too small and fragmented.

3) Northern Nigerian Village Agriculture

Village agriculture in northern Nigeria represents another contrast. The people, as exemplified by Nasarawa village, live in well-organized communities which produce some surplus for the local market. Farm workers spend time in other occupations. The system is monetized and, as a hand-labor economy, is fairly sophisticated. Population pressure on the land is fairly heavy in these village areas; farms tend to be small and fragmented, with an average size of 2.36 hectares. Mixed cropping is extensively practiced with a wide variety of crops. The system generally supports its hard working population but some food shortages occur in bad seasons; the population can meet labor demands of the farms. The system is fairly well monetized and the fundamentals of a market system exist.

These three hand-labor economies represent a system of farming which has evolved over generations to meet the basic needs of the people. The system maintains a balance and the people have confidence in its capacity to provide a sufficiency for survival. Any introduction of change may be seen from within the system as an intolerable threat of uncertainty against which safeguards are unknown.

Animal-powered Agriculture

Animal-powered farming is referred to by a variety of terms: mixed farming in Nigeria, bullock farming in Ghana, animal farming in Senegal and ox-plow farming in most other areas. Oxen power is relatively new for most parts of Equatorial Africa; only in Ethiopia is there a long tradition of using oxen. In Nigeria and Ghana, the first government support for animal

power was initiated in the 1920's and 1930's. In Francophone countries, emphasis on animals for farm power began in the 1930's.

Technical and Engineering Factors

1) Animal Utilization

Most animal implements are drawn by two animals, although in the light, sandy soils of West Africa, single animals are often used. In the East African highlands, 4, 6, 8 and even 12 oxen are used to plow or break the heavy soils, particularly after lying fallow for some time. This applies primarily to Kenya and Tanzania where the introduction of the western-type moldboard plow for deeper tillage has forced the use of tandem pairs. In contrast, the traditional Ethiopian breaking-plow or *ard* seldom stirs the soil below 12 cm. and only one pair of oxen is used. A large ridging plow used in Ghana and Nigeria on light soils may be operated with one pair of oxen only after rains have softened the soil.

More emphasis has been placed on improved animal-power in the Francophone countries of western Africa. Sales of animal equipment during 1958-1968 suggest a relatively high acceptance of animal-powered technology.

In Gambia, a series of programs and schools for training farmers and animals was started in the late 1950's by Moczarski.[10] These have been relatively successful in assisting subsistence farmers to enter the commercial agriculture stage. Moczarski developed a system of farming around a package of tools rather than just one basic tool as happened in Nigeria with the ridging plow. Use of an improved toolbar encourages the adoption of other improved agricultural practices and gradually builds an effective system of improved power farming.

2) Criteria for Successful Introduction of Animal Power

In each case of successful promotion there has been a concerted, continuous and well-supported program of government activities including ox-training, farmer-training, demonstration of better tools and provision for credit, along with adaptive research and cooperation between the extension service, research institutes, the government ministries and technical assistance programs. A great deal of time, money and effort is required to introduce a successful program of animal-powered technology as described for Senegal.[11] In Tanzania and elsewhere in East Africa, ox-plowing schools were

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[10]S.Z. Moczarski, Extension Specialist, FAO/UN, Ministry of Agriculture, Gambia, 1951-61.

[11]R. Bour, *Definition of Intensive Agricultural Exploitation*, (Institut de Recherches Agronomiques Tropicales (IRAT), Conference on Agricultural Research Priorities for Economic Development in Africa, April, 1968), p. 4.

established to train farmers and oxen in this new technique, but continuous government support was necessary to maintain farmers' interests.

3) Limitations in Present Development

It is very difficult to introduce new techniques which conflict with established attitudes. In the traditional cattle-herding areas of Equatorial Africa, there is great opportunity to employ animal-power in annual crop production. The present numbers of working oxen as compared to total numbers of cattle is practically negligible outside of Ethiopia. Cattle-herders and soil cultivators frequently are distinctly different groups tending to share few interests. In northeast Ghana the Kusasi people have learned to use cattle for work, but after field work is finished, the cattle are turned over to the Fulanis to herd.

Debilitating and fatal animal diseases prevent application of animal-powered technology in an area of approximately 11.7 million square kilometers of Equatorial Africa. Eradication of the tsetse fly probably would enable the tropical zone of Africa to stock an additional 125 million head of cattle.[12] Many of these cattle could be working animals. The problem of disease magnifies the many difficulties affecting the use of animal-power in Equatorial Africa. Much long-term research, constant effort, and close cooperation are required of all groups concerned with agricultural development.

Animal-powered Agricultural Systems

Two areas were selected as models for animal-powered farming systems: both are in economic transition. The first case is in the Chilalo Awraja of Ethiopia. The Chilalo Agricultural Development Unit (CADU) of the Swedish International Development Agency (SIDA) has organized a technical assistance package program including limited introduction of engine-powered agriculture into this predominantly oxen-powered area. The second area in the northeastern part of Ghana is essentially hand-powered. There, the Christian Service Committee has a small development program to introduce appropriate forms of animal-powered equipment. Some additional observations are drawn from Gambia and the Tanzanian experience with engine- and animal-power.

1) Chilalo Awraja, Ethiopia

The CADU development program is a multi-disciplinary approach with three main objectives: (1) to conduct experiments on the improvement of production and marketing of agricultural products; (2) to disseminate new agricultural techniques; and (3) to make feasibility studies on the improvement of transportation, education, training, public health, commerce and industry.

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[12] President's Science Advisory Committee, *The World Food Problem*, Vol. II., p. 277.

The farming of the area is essentially mixed. A variety of cereal crops is grown and all types of livestock are raised. The average farm size is 8.1 hectares, of which 5.1 hectares is under cultivation and the remainder grazed. Oxen provide the predominant form of agricultural power, although there are some 30 tractors, mainly owned by CADU, in the area. The area is in transition: improvements are being introduced to the local pattern of ox cultivation along with the introduction of tractor power. The case represents a farming system dependent on oxen power, with a fairly well-established commercial economy that can support a more sophisticated agricultural technology and commercial practices.

2) The Christian Service Committee, Upper Ghana

In northeastern Ghana the Kusasi people traditionally are crop farmers owning cattle but caring little about them. Mixed farming was encouraged by the government through the establishment of "bullock-training centers" during the 1930's. Since 1966, renewed encouragement has been given to oxen farming. Christian Service Committee personnel are working in this area: (1) to assist the local farmers in solving their most pressing technical problems; (2) to develop the adaption of animal-powered agriculture. Farmers are relatively poor and must use their own cattle, which tend to be too small and light to pull standard oxen equipment. The CSC approach to local problems is pragmatic and based on three important principles:

1. That careful study is given to specific local problems and adaptive research is carried out in the areas where new technology will be applied, and not at centers remote from the area;

2. That the intermediate stage of animal-powered agriculture is an important teaching device for demonstrating new cultivation principles;

3. That local instruction courses are appreciated when they come to grips with relevant local problems and are handled in terms, and in a medium of instruction, which can be assimilated by those attending the school.

3) Additional Observations on Ox Power

a) Gambia In 1955 the government of Gambia established the first ox-plowing school; by June, 1968 there were 320 trainees enrolled at 24 Mixed Farm Centres. Each trainee is a young man from 15 to 35 years of age who takes his own oxen to a center for a period of 8 1/2 months.

It has been estimated that ox cultivation can increase production of groundnuts and millet by about 33 percent, the area under cultivation by 33 percent, and gross income by 44 percent. Yields have not increased over those for hand cultivation, but in most countries in Equatorial Africa there is adequate land to permit expansion.

b) <u>Tanzania</u> In Tanzania the government has retreated from a policy of actively encouraging engine-powered mechanization of agriculture to one of more circumspect use of tractors and definite encouragement of oxen-power. Research, testing and training facilities to improve the animal-powered technology are being established. Oxen-power has been found more appropriate to the level of development of most areas and the level of understanding of most farmers. Reduced running costs, small repair costs for equipment, low replacement of draft animals, the multi-purpose nature of the animal and a minimal drain on foreign exchange are all factors contributing to the appropriateness of oxen for most of Tanzanian agriculture.

Engine-powered Agriculture

The application of engine-power enables man to become a director of almost unlimited power. However, engine-power is costly and, in order to utilize this power economically, high management and technical skills must be employed along with other modern inputs. The increasing use of mass communication media to describe what other nations are doing, the establishment and operation of successful commercial-type farms and plantations within African countries and the rising education levels, have awakened the small farmer to the possibilities of mechanical power.

Major advantages of engine-power are: (1) more thorough land preparation and greater speed of operations; (2) capacity to handle the heavier and more difficult soils more independently of weather and season; (3) ability to break heavy sods and grassland and turn under large amounts of vegetation; (4) more timely operations including early planting by optimum dates; (5) better weed control and inter-row cultivation; (6) efficient stationary power available for harvesting, threshing and processing; and (7) the possibility to double and triple crop land where adequate rainfall or water is available for irrigation.

<u>Technical and Engineering Factors</u>

The greatest problem is rational selection, operation and maintenance of machine systems so the costs do not exceed benefits. For the small farmer, this is a difficult requirement since the total price of his crops and the size of his holding restrict his potential income. As Le Quinio pointed out, "in French speaking West Africa, they have found that mechanization can only be profitable when applied to export crops."[13]

An engine-powered farmer must be a better-than-average farmer, and must

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[13]Le Quinio, *Minutes of Meeting of Specialist Committee on Agricultural Machinery Held at Northern Research Center* (Tengeru, Arusha, Tanzania: October 3, 4 and 5, 1967), p. 5.

achieve much higher yields to offset the higher costs of production. These costs tend to be high because of: (1) the need to clear and prepare the land thoroughly prior to tractor operation; (2) the high cost of imported machinery, equipment, attachments or additional implements for work diversification; (3) the difficulties of maintaining and repairing complicated machinery; (4) the lack of experience and understanding in managing costly machine systems; and (5) the high cash expenditure for operational supplies and services such as fuel and lubricants, tractor and implement repairs.

African countries are using several approaches to introduce engine-powered agriculture into communities. For the small farmer who wishes to hire machinery, several governments provide tractor-hire services; a few large farmers or contractors do custom work for others; cooperatives are formed to offer machinery services; or several farmers form a private machinery group. If a farmer desires to become an owner, he may buy a small power unit for his own needs; he may join with neighbors to buy a medium size tractor; or he may buy a larger tractor and become a farmer-contractor. Large quantities of machinery have been introduced through settlement schemes, group farming, or state and commercial farms in both eastern and western Equatorial Africa.

Engine-powered mechanization can range from a single operation of plowing to a completely mechanized system. There are very few examples of the latter in African agriculture even on commercial plantations; most hand-farmers find it to their advantage to utilize engine-power only when it offers a specific proven advantage. For the developing farmer as well as for the developing country, mechanization must be selective and, for a long time to come, it is likely to be incomplete.

Opportunity exists for the selective introduction of the most modern agricultural tools, machines and implements, but extreme care must be exercised in promoting, implementing and supporting these sophisticated levels of mechanization. Large commercial farms and plantations with adequate resources, management, previous experience, well-trained workers and established markets are able to exploit the economies of scale associated with high-volume production by employing engine-powered technology in at least part of the operation. However, partial and gradual mechanization is likely to remain pragmatically, the approach in most of Equatorial Africa. With an abundance of labor, many operations such as harvesting can still be performed economically by hand.

Experiences of African governments in operating tractor-hire services and doing contract work for farmers, settlements, group farms, state farms and various special schemes have proved exceedingly costly. Much of the machinery obtained by developing nations under grants, loans, and technical assistance programs, has been subsequently found to be unsuitable for tropical conditions. Maintenance and utilization has often been less than expected because local

capabilities of both operators and administrators have not been realistically assessed. Donor countries and machinery manufacturers frequently have failed to select appropriate equipment or to provide adequate training for its use.

Engine-powered Agricultural Systems

Engine-powered agriculture falls into three general categories: settlement schemes, tractor-hire services, and large-scale commercial farming operations. Selected sites of data are: the Middle Awash Settlement Scheme, Ethiopia, and the Block Farm Schemes, Tanzania; the Ministry of Agriculture Tractor-hire Service of Ghana and regions supplemented with operational data from the IBRD and the Kenya Tractor-hire Service and the Masai Wheat Scheme; Tendaho Plantations Share Company, Ethiopia, and large-scale commercial farming in Setit-Humera, Ethiopia, with some supplemental observation from Motoragri, the Ivory Coast.

1) Middle Awash Settlement Scheme, Ethiopia

The Middle Awash Valley Settlement Scheme demonstrates the way in which inexperienced farm settlers (nomadic Afars) can be introduced to the complexities of mechanized agricultural technology of large-scale cotton production. There are several major considerations which favor the success of this settlement. The area is sparsely populated and, apart from being the traditional grazing area for Afar herds and flocks, is undeveloped. The purpose of the scheme is the settlement of nomadic people in a more abundant form of living in an area where social pressures are increasingly antipathetic to nomadic traditional life. The scheme is based economically on cotton production in a relatively fertile area of a country with good internal demand for cotton. There is also the great advantage of proximity to the Melka Werer Research Station. The station was established several years before the 1964 Settlement and has experimental experience on which local farming enterprises can draw.

2) Block Farms, Tanzania

The Block Mechanization Scheme in Tanzania, was established in 1964-65 to use government tractors economically by amalgamating cotton fields into 121.4 hectare blocks. The scheme was based on the assumption that family labor could handle a larger cotton area, with mechanical assistance to cultivate additional land. Supervision, in the hands of the extension service, proved inadequate for the demanding administrative task of selecting farm blocks, mobilizing participant farmers and the timely deployment of tractors. Technically, the scheme also was disappointing in the failure of crops to reach yield expectations needed to meet the shift from low to high operational costs. The type of mechanization appeared appropriate for the area, but

de Wilde suggests that for so large an area as Sukumaland no single line of approach can be considered alone as appropriate. A differentiated approach is required for the development of a large agricultural area, incorporating circumspect planning, exploratory periods employing a pilot scheme, and establishing several development schemes appropriate to different levels of needs.[14]

3) Tractor-hire Service, Ghana

The tractor-hire service in Ghana provides an example of engine-powered implements available through a government-sponsored scheme to assist hand- and animal-powered agriculture throughout the country. There is evidence that the tractor-hire service is well received by progressive farmers and economical from the farmer's point of view. The services offered are costly from the government's point of view because of the vast amount of administrative detail required to operate such a service.

4) Tractor-hire Service, Nigeria

Between 1961 and 1967 an average of 182 wheel tractors were imported annually into Nigeria. It is estimated that there are currently 1,200 wheeled tractors in the country but only about 400 of these are used in agriculture. Farmers are convinced after using the tractor-hire service that tractor cultivation improves their income despite the problem of obtaining timely service.

There is now a move to encourage interested farmers to purchase the government-owned tractors. Encouragement takes the form of loans and credit accommodation. Also, private contractors are able to offer services at rates about 2 1/4 percent below government charges. There are indications that tractor-hire services in Nigeria may gradually move into the hands of private contractors.

5) Masai Wheat Scheme, Kenya

Fully mechanized wheat growing was introduced in the Masai region of Kenya in 1967. A total of 6075 hectares of land will have been brought into this scheme by 1969 using 50 tractors and complementary machines. The range of elevation from 1800 to 2800 meters is a distinct advantage with the cropping season much later at higher elevations; the equipment can be used over much of the year, gradually moving to higher elevations with each successive operation.

So far, machinery utilization has been good. The annual average area cultivated per tractor is 120 hectares and it is not uncommon for a 3.7 meter combine to harvest 1200 hectares in one season.

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[14] J.C. de Wilde *et al.*, *Experiences with Agricultural Development in Tropical Africa*, Vol. II, "The Case Studies" (Baltimore: The Johns Hopkins Press, 1967), pp. 437-443.

Yields on these virgin soils are excellent with 27 to 40 quintals per hectare. The Vertisol soils in East Africa are highly friable with self-mulching characteristics, but, if the soil is overworked, extreme pulverizing occurs.

6) Tendaho Plantations Share Company, Ethiopia

Tendaho Plantations, Ethiopia, exemplifies a large-scale commercial plantation. The entire land concession, in the Danakil Desert, covers 10,000 hectares and at present the Plantations cover 5,500 hectares. This case represents a highly mechanized operation in the early cultivation stage with hand labor reaching a peak of 7,000 workers at the peak of the picking season in November. Some 90,000 quintals of cotton were estimated for the 1968-9 season, which is sold as ginned cotton in the domestic market and the cotton seed is mainly exported. Estimated budget production costs estimated $366,830 would be paid out in day laborers wages in 1968/9. Export potential is extremely important, especially as Tendaho produces high quality cotton which competes on the world market.

7) Setit-Humera, Ethiopia

In the Setit-Humera area, in northwest Ethiopia, limited oxen farming has been practiced for 50 years. Today, it is an area of rapid, unplanned economic expansion. Recent estimates show 280 farmers owning more than 400 tractors. The area is of considerable interest to the government and development agencies because of its high economic potential. Some 60,000 migrant workers annually come into the area for weeding and harvesting. However, the area cannot be farmed on a large-scale economically without engine-powered technology, despite much use being made of hand labor. The area is farmed entirely by individual entrepreneurs, most of whom have come in the past ten years. Mechanization already plays an essential role in the agricultural system of this area. Major problems are to understand the macro-economic organization in which the individual farmer is a single functional unit, and to determine how the already established system may be supported to maintain the economic prosperity of the area. At present there is real danger that expansion may be stifled due to inadequate economic infrastructure. This case demonstrates the critical need for an adequate infrastructure in order that engine-powered farming may proceed without inhibition.

8) Motoragri, the Ivory Coast

The Ministry of Agriculture of the Ivory Coast initiated in April, 1965, a detailed study of means to achieve more rapid agricultural development. The primary objective was to move away from dependence on coffee and cocoa

by diversification with pineapples, teak, vegetables, palm oil, cotton, rubber, rice, sugarcane and tobacco. Since less than 10 percent of suitable agricultural soils are used, there seems to be great scope for clearing land for priority crops. Following this study, Motoragri was established as an autonomous operation of the Israeli Cooperative Agridev through agreement between the governments of the Ivory Coast and Israel.

The work of Motoragri consists of clearing and subsoiling land for farming; seeding and fertilizing; construction of earthen dams, secondary roads; and clearing new village sites. Ivoirian staff is being trained to take complete control of the operation and the 30 Israeli expatriates who manage Motoragri are to be gradually phased-out over a period of ten years.

General organization is extremely efficient in management, marked by careful record keeping, rapid mobility of managers, and good communications by short-wave radio.

Motoragri is equipped with 226 tractors, 68 cars and 7 trucks purchased by the Ivory Coast government; 85 percent of the tractors are operational at any time. This high level of performance is achieved through a system of regional and field workshops, and a major workshop located at the central station in Abidjan to handle rebushing of crawler tracks, engine and transmission overhauls, and other major repairs. About 30 percent of total workshop operations are done at the central station.

Of major importance at this sophisticated level of mechanization in Equatorial African agriculture are the following aspects of Motoragri's operation: (1) the efficient operation of heavy and complex engine-powered machinery; (2) extremely intensive management supported by a close sytem of record-keeping; (3) scheduled phase-out of expatriate management to be replaced by a trained indigenous management; and (4) the training of Ivoirians to assume responsibility at all levels of management.

Laterite Soils and Their Management in Relation to Mechanization

The important ecological factors of soil and rainfall were discussed above. After having considered different forms of mechanization, it is essential to consider their effect on the laterites of Africa.

Laterite is a highly weathered material rich in secondary oxides of iron, aluminum, or both. It is nearly void of bases and primary silicates, but may contain large amounts of quartz and kaoliorite. It is either hard or capable of hardening on exposure to alternative wetting and drying. True laterite interferes seriously with land use in Africa. Clearing small areas for cultivation in systems of shifting cultivation or large areas for engine-powered cultivation can expose the soil sufficiently for serious laterite hardening to occur.

In Africa about 18 percent of the total land surface is laterite. It has been estimated that 5,338,000 square kilometers is laterite and associated soils. This is the most extensive type of soil in Africa after desert soils.

Yields of most field crops are low on laterite soils but certain crops such as tobacco, sugar cane, turmeric, ginger, and sweet potatoes are usually satisfactory. Tree crops are good since they are well adapted to laterite soils: tamarind, cashew, cassava (tapioca), coconut, banana and teak.

Three conditions are necessary for the hardening of laterites: (1) adequate supply of soluble iron either by an inflow of iron from surrounding areas or by an outflow of other constituents and a resultant concentration of existing iron; (2) alternating wet and dry seasons of approximately equal durations and sufficient rain during the wet season to continuously saturate the zone of iron segregation; (3) level land surface that has a slowly permeable layer where the iron concentrated horizon can develop during the wet cycle in a periodic water table or at least in a zone of saturation.[15]

It appears that the presence of vegetation is the only condition which can prevent, or reverse, this hardening process. Trees and other perennial woody plants are most effective. Thus, both the preservation and establishment of vegetation is important to break up laterite crusts and reverse the hazard of hardening.[16]

Soil research must be an integral part of all mechanization research in Africa. Although highly weathered tropical soils have good surface soil structure when first cleared, what happens to this surface soil structure, after a period of continuous cultivation, is a critical problem. Soil capping (surface crust formation), resultant surface soil erosion, and the hardening of a groundwater laterite layer are the results reported by some researchers. Massive research efforts must be concentrated on these physical problems before continuous soil productivity under mechanized cultivation can be assured in Africa.

Engineering and Technical Analysis of Agricultural Production Operations

Introduction

In the developing countries of Equatorial Africa, more and better machinery is needed, not as labor-saving devices, but to increase the productivity

[15]Lyle T. Alexander, and John G. Cady, *Genesis and Hardening of Laterite in Soils*, Technical Bulletin No. 1282 (Washington, D.C.: U.S. Department of Agriculture, Soil Conservation Service, 1962), p. 4.

[16]*Ibid.*, pp. 5-12.

of the small as well as the large farmer. With the realization that for many decades to come, the bulk of all farmers in Equatorial Africa will be using hand- and animal-powered tools and practices, Chapter III is devoted to a detailed description of many of the currently-used small tools, along with improved tools and machines that could be introduced on a broader scale.

In the process of gathering and evaluating information for this Study, it quickly became apparent that there was no single source of readily available information to present an over-all picture of the tools and processes actually in use in Equatorial Africa at the present time. It is necessary, however, to know current developments before improvements can be planned.

Government officials, planners and administrators must be well-informed if they are to deal with present, practical reality rather than theoretical goals. These officials must be cognizant of the improved tools currently available within Equatorial Africa and from other regions. For example, tools that are presently performing satisfactorily under similar conditions in Asia and in the Far and Near East may be suitable for use in parts of Africa. There are tools which can be easily introduced to improve present traditional practices, but tests must be conducted and tools evaluated under carefully controlled programs of adaptive research and farm trials to ascertain their suitability and profitability to small African farmers. The Study endeavored to ascertain first-hand the tools and practices in use, and to present facts concerning their utilization. This information is presented in Part Two of this report with the hope it will assist future work and serve as a basis for proposed follow-up national and regional research and development programs. This accounts for the detailed nature of Chapter III which represents the practical basis and foundation for constructively improving the essential hand- and animal-powered methods of production. These, in turn, will lead to utilization of improved mechanical power at all levels of agricultural production.

<u>Present Use of Power in African Agriculture</u>

At the present time, engine and mechanical power available to the farmers of Equatorial Africa averages only a fraction (0.05 hp.) of the more than one horsepower per hectare utilized by farmers of Europe and the United States. This lack of power makes it difficult to prepare seedbeds efficiently and with timeliness, and to place seed and fertilizer accurately. Improved tools and methods are needed to control weeds, insects and disease, all of which can contribute markedly to improved yields and to the economic utilization of mechanization inputs.

The President's Science Advisory Committee stated that,

> With one or two exceptions, an analysis of yields in various countries indicates that a power level approaching

> 0.5 horsepower/hectare is needed for an efficient agriculture. It is estimated that $500 million will need to be invested by the end of this century in plants for the production of farm machinery in the developing countries. The total capital investment, including components which can best be imported, will approximate $2 billion.[17]

If 0.5 hp./ha. is needed for an efficient agriculture, and Africa averages only 0.05 hp./ha., Equatorial Africa presently has only one tenth of the minimum requirement for efficient production.

Receptiveness of African Cultivation to Change

There is a large latent demand for improved tools and machines in the countries surveyed in Equatorial Africa. This Study and other surveys and research projects have shown that the small African and Asian cultivators are not against change. They do not request different tools because they do not know of anything better. Hence they continue to use what they have.

Contrary to popular misconception, most farmers want to improve their farming operations and to have improved tools with which to work. Studies and seminars in Ethiopia,[18] Turkey, Iran, Afghanistan,[19] and Nigeria,[20] for example, have discovered that farmers want improved tools but are unable to purchase them because of lack of knowledge, lack of cash, unavailability locally, or because of other reasons beyond their control.

In discussing animal-powered or engine-powered agriculture in the tropics, it must be kept in mind that within each level of mechanization there are necessarily degrees of application of hand power. Rarely, if at all, is there what can be called a pure animal-powered system or a pure engine-powered system. Even very advanced systems using large tractors, retain extensive use of hand power and animal power in complementary operations.

Hand Tools

In Chapter III, some of the more common and a few distinctive indigenous hand tools are described. These tools are made by artisans or blacksmiths

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[17] President's Science Advisory Committee, *op. cit.*, Vol. I, p. 87.

[18] Bo Bengtsson, *Cultivation Practices and the Weed, Pest and Disease Situation in Some Parts of the Chilalo Awraja*, Publication No. 10, (mimeographed) (Addis Ababa: Chilalo Agricultural Development (CADU), Swedish International Development Agency, 1969).

[19] Central Treaty Organization, *Traveling Seminar for Increased Agricultural Production*, Regional Tour, (Ankara: CENTO, April, 1962), p. 160.

[20] M. Tiffen, *Innovation and Changing Patterns of F rming in Gombe Emirate, Northeastern State, Nigeria*, (mimeographed) (Samaru, Za.ia, Nigeria: Ahmadu Bello University, Institute for Agricultural Research, Rural Economy Research Unit, 1968), p. 7 and Tables.

locally with simple equipment. In some areas the tools show more refinement and finish. There are improved tools within regions of Equatorial Africa which could be more widely distributed, as well as tools from other countries that offer possibilities for introduction.

Digging and Weeding Tools

The Nigerian short hoe, the *garma*, is an excellent short-handled digging, weeding and all-purpose tool. Funke, extension advisor in Kenya and formerly extension advisor in Nigeria, says it is far superior to any hoe now in use in East Africa which he has seen.[21] It is light, well-balanced when fitted with the proper handle, easy to use and very inexpensive at $0.14 to $0.28 for the metal blade and a homemade handle. This tool was designed for the farmer who has grown up with short-handled tools and who has developed muscles, preference and skills for this style of tool. Where short handles are preferred, the curved blade and the shape of the handle make this tool functionally well designed. The major deficiency is the quality of metal and its lack of temper.

Improved weeding tools should be introduced along with planting crops in rows and other improved practices. Where long-handled tools are already in use, they can be improved by introducing pulling, pushing, or combination push-pull hoes which permit much faster weeding along a row. They cannot be used to any advantage, however, unless present cultivation practices also are changed from broadcasting and random mixed cropping. The introduction of a tool, then, logically goes along with an improved cultivation practice. An improved tool must have a purpose other than simply replacing another tool; it should permit or aid the adoption of other beneficial practices.

Cutting and Chopping Tools

Another tool used in every Equatorial African country surveyed is a large knife or machete. While most are made by local blacksmiths, farmers recognize the superior quality of carefully-engineered factory models made of top-quality high-carbon tool steel. One factory in Nigeria produces machetes, under the "Crocodile" name, and farmers have built up a strong preference for this trademark. As one official remarked, once they find out a product is good, they are willing to pay more for it; African farmers are, in fact, very brand-conscious. One company makes 28 differently sized and shaped models, each designed for a particular job with handles to fit specific use.[22]

One tool used almost universally in Equatorial Africa for harvesting is

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[21] George J. Funke, USAID Extension Advisor, Kenya, Ministry of Agriculture, Personal Communication, October, 1968.

[22] G. Hardwich, Hardware Manager, G.B. Ollivanti, Ltd., Lagos, Nigeria, Personal Communication.

the sickle. Except for large commercial farms, plantations and government-sponsored mechanized schemes using combines, practically all grain is cut with this small implement. The scythe is a more efficient tool, but its introduction and acceptance has been very slow because it is harder to use, more costly and requires frequent sharpening. There is room for improvement of the sickle or for development of a harvesting tool to take its place. As cropping areas and yields increase, labor for harvesting becomes a critical problem. It may be that the scythe will never be accepted; it or any other tool obviously will not be unless it is demonstrated, promoted, stocked and made available at the local level at a reasonable price. A machete or small-tools factory could produce the blades locally, but the extension service must work with farmers in the field and train them in order to promote purchase and use.

Threshing, Grinding and Cleaning Tools

Hand threshing is a tedious process. Where animal power is not available, simple improved hand-operated threshers could greatly increase the productivity of men performing this task. Nothing has been done to help the small farmer with this operation. On a strictly subsistence level, the high manpower requirements have not been important, but they are of major concern to the emerging market-oriented farmer who has other ways in which he could use his energy and time more profitably. Small engine-powered threshers should be tested and introduced in the hand-powered farming areas where larger and more efficient tractor threshers are not available.

Hand grinding is another time-consuming and laborious task. Africa can learn from the Vietnamese treadle mortar which increases the speed and output of this simple process by 40 to 60 times. With the African hand mortar and pestle, for example, it takes 4 hours to convert one kilogram of brown rice into white rice; while with the Asian treadle mortar, 12 to 18 kg. of brown rice can be converted into 10 to 15 kg. of white rice in only one hour. This marked increase is obtained through the more efficient use of a simple beam-action pounding lever.

Almost as time-consuming as hand cutting and threshing is the job of cleaning grain in the wind. When there is no breeze, the work must wait. A simple hand- or foot-operated winnowing fan can markedly expedite this process and produce a cleaner product in a fraction of the time. Again such devices are being made in the Middle East and in Asia, but they have not been introduced to the small farmer in Africa. Hours of increased productivity could be realized with the introduction of simple hand-turned or foot-operated winnowing fans. Furthermore, they could be made locally, to create new jobs and new wealth for developing countries.

Local Manufacturers and Repair of Tools

The small hand tool is such a low-profit item that few companies want to get involved in its manufacture or distribution. One company, the Scovil Hoe Company of Higganum, Connecticut, is very much interested in producing high-quality steel blanks for final processing in small factories in developing countries.[23] They have the steel and the fabricating facilities but need help in determining the best design of tools for each major crop and cultivation area in developing nations. Since most African countries must import their steel, it would greatly expedite the production of good tools if the correct quality of steel and approximate shape could be stamped or forged in modern overseas foundries and shipped in bulk to the recipient nations. The important factor is to determine, by actual field trials and evaluations in the hands of the using farmer, what constitutes the better tool and what changes need to be made.

The local blacksmith or artisan is an important link in the distribution and service chain. Without his approval, acceptance and ability to repair and sharpen the better tool, it will not be recommended by him. He also must be taught how to heat and work the metal or he can ruin its superior quality and functional advantage. While local blacksmiths have served local needs with their unsophisticated tools and facilities, they can be taught new skills (*e.g.* Shambaugh developed a simple hot metal holder to permit working red hot material easily, safely and effectively).[24] There is need also for a larger number of skilled artisans in local villages. Often cultivators must travel from 10 to 60 km. to the nearest market to purchase or to repair a tool. Under such conditions, anything better than native stone or wood is not likely to be thrown away even though it may be worn out by other standards.

It has been observed that indigenous tools are rarely sharp or ever sharpened. This is partly due to the scrap material from which the tool is made and partly to the method of fabrication and metal-working techniques. A great deal of energy is wasted in forcing the action of dull tools.

If the hand-powered Equatorial African farmer is to become more productive, he must have access to improved tools. He must have tools which permit him to do his work more effectively, not just to save labor, but to do more work with greater accuracy, speed and ease.

Animal Tools

Animal power is important to the further development of agriculture in

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[23] DePaul, *op. cit.*

[24] T.J. Shambaugh, Jr., *Blacksmiths Tool Holder for Chisels and Punches, How to Make It, How to Use It*, Special Report 69-6, (mimeographed) (Samaru, Zaria, Nigeria: Industrial Development Center, 1969).

Equatorial Africa. In many of these countries its use and improvement tends to be overlooked although very satisfactory improved basic animal-drawn tools are available for promotion. Finally, it is evident as with hand tools that farmers not only need but want better equipment in most areas.

Limitations Affecting Animal-powered Systems

The two studies mentioned earlier draw attention to cases, in Ethiopia and Nigeria,[25] where progressive farmers have requested assistance from their governments to make available improved animal-drawn equipment and to teach them how to use it. However, little attention is being given to this important area of development due to the ever increasing demands on busy staffs in agricultural departments and ministries of developing countries.

With so much emphasis on more sophisticated equipment, such as jet aircraft and 60 to 100 hp. diesel tractors, there is a tendency for high-level planners and technical experts to consider animal power out-dated, unimportant or even retrogressive. Frequently, officials have little contact or understanding of the problems of the small farmers. The small farmer needs help within the contemporary context of his environment with its limitations, and commensurate with his available resources and present abilities.

The practical farmer, the real decision maker, is far removed from the level of government planning officials trying to help him, thus there is little chance for feedback. Great numbers of capable agricultural extension field workers are needed who can speak the farmer's language and understand his problems. Extension field workers must know far more than the farmer, be well-grounded in the practical application of proven technology, be able to demonstrate any recommendations with confidence, and have experience to make intelligent judgments in selection and application of new proven practices. Furthermore, field workers must be personally interested in the farmers' welfare.

One purpose of Chapter III is to review some of the most promising developments in animal-draft equipment and to show that considerable equipment already is available. Major implements are discussed which can make definite contributions to increased efficiency and productivity for the animal-powered farmer: animal-drawn toolframes and toolbars and their attachments; seed planters, cultivating and weeding implements; threshing and harvesting equipment; winnowing, cleaning, grinding and processing machines; spraying and dusting tools; irrigation devices; and farm carts and wagons.

There are still many opportunities to improve further present implements and to develop new equipment to employ animal power more effectively. One of

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[25] Bengtsson, *op. cit.*, pp. 14-15 and Tiffen, *op. cit.*, pp. 5-6.

the problems has been the relatively high cost of improved animal-drawn tools; volume demand has been so low that few firms can afford to go into the manufacturing business and even fewer can stay in it. This low volume creates high prices which can be reduced only when sufficient promotion and effective extension work has created a demand great enough to keep a factory busy throughout the year. Individual governments can support such a program but support must be sustained over a long period of time to avoid slow and erratic progress.

For the hand farmer, primary tillage and timely land preparation remains the critical task. Animal power with its ability to break, turn or ridge larger areas more quickly, has enabled the farmer to overcome this bottleneck. However, if the plow is his only tool, he is immediately confronted with another serious problem: he cannot look after and weed by hand all the land he can till and plant with animal power. Weeding becomes the limiting factor in intensified expanded animal-powered production when all operations subsequent to tillage must be done by hand. This is pointed out by Bengtsson in Ethiopia[26] and by Shambaugh in Nigeria.[27]

Some farmers do their first weeding with the plow, in a thinning process, but this practice is far from satisfactory. Implements are needed which are specifically designed for this purpose. While they are available and used in large numbers in Asian countries, they are seldom seen in Equatorial Africa other than in Senegal. Several types of simple, fixed or expandable hoes are inexpensive and suitable for the farmer who already owns a ridging plow or an improved plow of any kind.

Promising Developments in Animal Implements

For the capable and progressive farmer, a better choice would be one of the multiple-purpose toolframes or toolbars which are available in both western and eastern Africa. Manufacturing facilities have been established in Senegal, Kenya, and Nigeria to produce these tools locally, but the demand was so low due to the lack of effective promotion and extension support that the factories in the latter two countries were forced to close.[28] Large manufacturers are producing very satisfactory animal tools in France (Mouzon, Constructeur A. Luzarches) and in England (John Darbyshire and Company, Ltd.).

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[26] Bengtsson, *op. cit.*, p. 45.

[27] T.J. Shambaugh, Jr., *Bornu Complete Tillage Machine*, Special Report No. 68-8, (mimeographed) (Lagos: USAID/Nigeria, 1968), p. 1.

[28] The SISCOMA factory in Senegal produced 1,229 Polyculteur models in 1963 (but none since), and 492 Ariana models in 1967 and 1968. Heat Exchangers Ltd. in Nairobi state that they have only sold 100 units of the Ariana in three years. With regard to the Kano factory in Nigeria, see also D.W.M. Haynes, *Papers on Agricultural Engineering in Northern Nigeria* (Samaru, Zaria, Nigeria: Ahmadu Bello University, Institute for Agricultural Research, 1964), Section III, Appendix, p. 1.

The farmers like these tools and want to buy them, but they need assistance since the cost of the implement is beyond their resources. However, merely providing the tools on credit is not enough. An intensified training program and supervised credit and farm-planning service are required to make sure the improved power and implement systems are put to work raising better crops on more land with greater labor utilization.

With a basic toolbar, the farmer can add other attachments at very reasonable cost as he gradually enlarges his operations and begins to utilize other inputs to improve his farming system. Currently available are attachments for tillage, weeding, seeding, cultivating, and carting plus several harvesting tools for lifting groundnuts. Many more attachments could be made available, including an engine power unit to take the place of oxen, if and when it becomes economically possible for the small farmer to raise the level of mechanization.

One of the greatest deficiencies in animal-powered tools is the lack of effective threshing, cutting and harvesting machines. The sled-mounted knife cutter can be made easily for cutting stalks of maize, sorghum, millet and guinea corn, but no satisfactory simple machines are available for cutting small grains, grass and forage crops. A new type reaper made in France by Mouzon Freres is just now being introduced in Senegal.

In all probability, threshing machines and processing equipment can be more economically and efficiently operated by small stationary engines which can either move to the fields or be located semi-permanently. In the meantime, however, the Indian Oplad type of rolling disk-thresher may be the most economical answer for the many African farmers now threshing with animal hooves.

The development of an inexpensive and durable two-wheeled animal cart remains to be solved for the majority of animal-powered farmers. While research institutes, experiment stations, universities, and foreign technical assistance programs have worked on designs and have built numerous models, no completely satisfactory cart is commercially available at a reasonable price. An ingenious idea was developed by Shambaugh in Nigeria, using the rear half of an imported, heavy-duty farm wagon. It requires only a tongue in place of the reach, and the addition of a locally-made box, to make a very sturdy, roadworthy and high-capacity cart. Surprisingly, it costs less imported than most light carts with half the capacity which have been fabricated locally in small numbers.

The addition of a cart to the farmer's tools can be a very important stimulus in helping him to adopt other new practices. With load-carrying mobility, he has incentive to raise more crops and to seek out new and more distant markets. He can do custom hauling for neighbors to enhance his potential cash return and acquire additional resources to purchase more of the

proven production-increasing inputs. In other words, a simple cart can greatly broaden the farmer's horizons and increase his income.

Engine Tools

In Chapter III different degrees and types of engine-powered tool systems have been considered. Some of the advantages, features and capabilities of both small and large engine-powered systems have been compared. Individual tools with special relevance in agriculture in the hot, low-elevation and temperate, high-elevation tropics are discussed briefly.

Space does not permit a more thorough coverage of the great variety of tools largely developed elsewhere which could be utilized in Equatorial Africa by modification and adaption. How effective they are, whether changes in current production models must be made to adapt them to Equatorial African conditions and tropical climates can be evaluated only by field trials, experiments and adaptive research.

Engineers, agronomists and economists who have had considerable experience in the tropics can make tentative evaluations about the suitability of machinery for use in tropical agriculture. Careful evaluation before recommending that certain machines or implements be imported for trials and testing can avoid the importation of many unsuitable implements and tractors. There are many well-designed, standard-size machines and power units that can be used in Equatorial Africa with little or no modification, when wisely selected, competently operated, properly maintained, and fully utilized in commercial-type farming operations on both large and small farms.

Small Walking-type Tractors

Small engine-powered systems may be classified under two categories: single-axle power-tiller units and attachments of 4 to 10 horsepower, on which the operator does not normally ride; and larger dual-axle tractors and attachments of 8 to 15 horsepower, which are in reality scaled-down models of conventional farm tractors. There are units both smaller and larger than these, but this range comprises the most popular and perhaps, most useful sizes.

It should be pointed out that many, if not most, small tillers and tractors are not designed for the small farmer who must make his living from tilling the soil. Most small power units made in Europe, the United States and Japan are made for weekend gardeners, for estate maintenance, or for special jobs such as golf course maintenance and rice paddy cultivation. They are not designed for rugged, hard work, hour after hour, or for operation in tough soils, extremely hot, dusty or muddy conditions. They generally are too light, too complicated and require too much attention; they are underpowered, are equipped with small and ineffective drive wheels.

Because of the shortcomings of many small power units, officials, engineers and agronomists alike, tend to conclude that the small tiller or tractor is not suitable and has no place in the small cultivator's farming program. There is a great deal of controversy over small engine-powered equipment, whether it fits into the agriculture of developing countries and just what kind of farmers, if any, should be using it. There is ample evidence, however, in Japan, the Republic of China (Taiwan), Korea, India, Iran and the Philippines, that certain small tractors can be very beneficial and do many tasks more economically than hand or animal power, especially in wet land preparation.[29] Tests also have been made by several machinery-testing units in Asia, Africa, and Europe on several models which have proven suitable for dry upland cultivation.[30] These units can be used for farm work and are durable and simple enough to stand up under severe operating conditions, with a minimum of maintenance and care.

A brief description and conclusions of tests made to determine suitability and performance are given on two of several tillers being sold in Equatorial Africa: the Titan Merry Tiller and Landmaster L-150, both made in England. Modified Japanese-style models are currently being manufactured in a number of Asian countries including Korea, Taiwan and India.[31] There are some suitable small tiller- and tractor-type machines which can compete economically with hand and animal power when used by trained people. They must, however, be supported by a responsible dealer network.

Furthermore, the successful use of these small tillers or tractors depends more upon the man who is using it than is the case with large power units. Skill in handling the machine and the desire to do a good job have considerable influence on the quality of work and productive capacity. Cooper reported on the test of the Titan Merry Tiller, "as with most motorized cultivation, the quality of work depended largely on the operator's desire to produce good results. Under the conditions encountered during the test, the machine was capable of producing good work."[32]

At this stage of development in Equatorial Africa, there is perhaps a need to be very cautious and selective in introducing small power units into the agricultural sector because of the small farmer's traditional lack of mechanical background and because of the shortage of adequate sales and service facilities to support him in rural areas. Unless the distributor

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[29] *Record of Expert Group Meeting on Agricultural Mechanization*, Vol. I (Asian Productivity Organization, June, 1968), pp. 52-54.

[30] S.W. Cooper, "Test Report on a Walking Tractor", *Kenya Farmer*, (reprint, June, 1966).

[31] *Record of Expert Group Meeting on Agricultural Mechanization*, pp. 93-4 .

[32] Cooper, "Test Report on a Walking Tractor".

has trained staff and locally-based units equipped to back up any machine sold, it becomes unwise for the average farmer to invest in any tool he or the local blacksmith cannot repair and maintain.

The Singer Sewing Machine Company is attempting to overcome past shortcomings of small tractors by introducing the Landmaster tractor and attachments together with a very intensive service and farmer training program. In addition to their numerous established retail sales and service centers throughout Kenya, for example, they are providing mobile demonstration and service vans which travel throughout their territories. They guarantee free service to the farmer for the first year, and sometimes for the life of the machine; they will not sell a tractor unless they have access to it and can work closely with the farmer and service the machine regularly.[33]

Manufacturers find this type of promotion expensive and slow, but they believe it is the only way to effectively introduce small power machinery to the African or Asian farmer. That this type of promotion is neither easy nor inexpensive is indicated by Stanley who states,

> We have succeeded in putting Landmaster machines into many countries but it has always been hard work, although wherever we have succeeded there have been immediate signs of improvement in productivity so far as volume and quality are concerned.[34]

<u>Small Four-wheel Riding Tractors</u>

The economic value of small four-wheeled tractors has not been clearly established in Equatorial Africa. There are a few machines adequately designed which can be adapted to local conditions to perform effectively in rural Equatorial Africa. They must be carefully selected, tested and evaluated before any attempt is made to introduce them on a mass scale. This research needs to be done throughout Equatorial Africa and is a logical activity of a national research program on machinery evaluation and development. Most small tractors cost proportionately more per horsepower than the larger standard sizes because of the very low production rates and the relatively high cost to sell and service them. The profit margin is much smaller so the dealer must sell many more units to pay his business overhead; and yet the cost of doing business and employing capable mechanics is the same.

Several models are described briefly in Chapter III. The Self-Help Organization[35] has distributed many of the Self-Helper tractors to developing

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[33]Kenneth Parkins, Landmaster Sales and Service Representative, Singer Sewing Machine Company, Nairobi, Kenya; Personal Communication, October, 1968.

[34]S.S. Stanley, Expert Sales Division, Landmaster Limited, Nottingham, England, Personal Communication, March, 1969.

[35]Self-Help, Inc., Waverly, Iowa, 50677.

countries but no records of tests or evaluations were available for Africa or similar areas. Boshoff, agricultural engineer at Makerere University College, also is developing a small tractor from standard commercially-available parts which he believes will satisfy the farmers' need for additional power above or perhaps complementary to oxen power.[36] Several prototype models have been assembled but test reports or work studies are not yet available.

A brief discussion is given for a few of the many small engine-powered threshers, shellers, winnowers, water and irrigation pumps which can play a vital role in the agriculture of developing countries. Not very many of these machines are in use today, but the outlook is very good and will develop rapidly once the basic field techniques are established and the educational level of the next generation of farmers advances.

The development of adequate roads and communications systems along with associated businesses and small industry can accelerate the introduction and acceptance of improved equipment. The use of small engine-powered pumping sets for irrigation in the arid and semi-arid regions with potential year-round production is especially significant since they can remove the main obstacle to production when an adequate supply water is available.

Standard-sized Farm Tractors

While large engine-powered equipment are likely to continue to have a growing role in the mechanization of Equatorial African agriculture, it will be a long time before the average small farmer will be able to own and operate his own unit. Thus, government hire services and private contractors are one method of expanding the facilities for primary tillage and specialized services to emerging farmers. Settlement schemes, cooperatives and commercial-types of farming operations are another method of mechanizing and performing collectively most of the basic tillage and cultivation operations. Depending upon the crop, weeding, harvesting, cutting and threshing also may be done. Thus, the potential impact of large engine power is great, but for many years to come is likely to affect only a small percentage of Equatorial Africa's millions of hand- and animal-powered farmers.

Thus, no attempt has been made in Chapter III to discuss all implement and equipment associated with conventional large-scale and specialized engine-powered farming. A few examples have been given indicating trends and opportunities for large engine-powered machinery. In Africa, by and large, the selection, application, operation, care and maintenance of big machines

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[36] W.H. Boshoff, Makerere University College, Faculty of Agriculture, University of East Africa, Personal Communication, February, 1968 and March, 1969.

will rest with a few farmers and large commercial farming operations, both public and private. The small farmer will take advantage of big machine and tractor performance where it is available and when he finds it to his economic advantage to do so. But, generally speaking, it will not be his concern to see that these machines are wisely selected and efficiently utilized.

There are many pitfalls plagueing the effective and economic employment of expensive high-horsepower tractors and machinery in developing countries. Many private contractors as well as governments lack adequate information about the real costs of owning and operating machinery. There appears to be a general tendency to borrow in order to meet current expenses. Frequently, only direct-operating expenses are met, thus when the equipment needs replacement, there are inadequate funds since depreciation costs have not been covered.

There are many good tractors and large-size engine-powered machines which can be used as effectively for agricultural production operations in the tropics as in any other area. Some modifications may have to be made to fit them to special climatic conditions such as high-temperature lowland operations or high-altitude upland areas.

Innes and Scott state that there are four main problems relating to the performance and reliability of tractor operation under tropical conditions: radiator blockage; fuel filtration; electrical troubles; and air-filter maintenance. Furthermore, maintenance and repairs are very important in "working with unskilled drivers in areas of [East Africa] where constant supervision and inspection is either impractical or too costly."[37] A big problem is obtaining or training skilled, capable and responsible operators. The absence of tractors and machines to be repaired is the real measure of an effective maintenance and training program.

There has been some inclination by foreign donor nations to neglect giving adequate attention to the suitability to local African conditions of much equipment and tools given in the form of gifts or low-cost loans. These poorly designed wood, iron and steel machines would be difficult for a developed nation to use effectively and keep in good repair, let alone a nation struggling to develop its agricultural and industrial economy. The high cost of repair parts, the lack of experienced mechanics and technicians, the lack of supervision in the field, the improperly trained and inadequately motivated drivers, and the almost complete lack of soundly administered and business-oriented organizational structure have all contributed to the failure of machines and power units and the complete mechanized system.

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[37] D. Innes and P.F.C. Scott, "Tractors Modified to Suit East African Conditions," *Journal of Agricultural Engineering Research*, Vol. 6, No. 1 (1961), pp. 79-82.

Many African governments purchased directly from the manufacturer through government-owned or controlled trading and import companies. They by-passed established importers, dealers and service organizations who normally handle agricultural machinery. Spare parts were not ordered in some of these initial deals. As tractors broke down, they were cannibalized to keep others going. Such conditions of operation have added to the ordinary problems of using and servicing farm machinery.

Training is very basic to the successful introduction and continued successful use of agricultural machines, whether large or small, animal- or engine-powered, government or privately-operated. A thorough program of training and instruction, with adequate follow-up, must be put into effect from the very beginning. If the correct procedure can be taught and made a habit, repeatedly checked and corrected as soon as deficiencies or faults show up, then skilled and responsible machinery operators, mechanics, technicians and supervisors can be produced.

That this can be done is shown by the success of Motoragri in Ivory Coast in training an Ivoirian staff of over 750 employees, much of the training done on the job. While these people are well-trained, they are still supervised by qualified technical staff until they gain sufficient experience to take over complete responsibility. Initial training is not enough; there must be progressive training to keep regular employees on their toes and to upgrade the best employees into positions of higher qualification and responsibility. There must be a continual program of employee evaluation, follow-up and corrective training or disciplinary action if the employee fails to measure up to established standards. Even in the best organizations there will be some members who are misfits or incompatible workers; and for the good of the organization they must be released.[38]

Another type of training program is conducted by the Narosurra Mechanization Training Scheme in Kenya. In this intensive three-month course of practical training, individuals are trained to be self-reliant and to go out and work on their own without direct supervision. Many of the graduates have become private contractors or are managing large farms using engine-powered machinery.[39] Both of these programs are described in Chapter V.

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[38] Arie Barkol, Director General, Motoragri, Abidjan, Ivory Coast, Personal Communication, May, 1968.

[39] Michael Low, Executive Director, Narosurra Farm Mechanization Training Scheme, Sabatia, Kenya, Personal Communication, October, 1968.

Analyses of Present Farming Systems

Engineering and Technical Analysis

Hand-powered Systems

If agricultural production is to be improved for the small African farmers, they must be informed about better tools and methods of using them. There are several ways in which improved hand-operated tools can assist small farmers and extend this efficiency. The first is to increase yields and the productivity of relatively scarce inputs by making efficient use of available resources. The second is to expand the size of operations to utilize fully available manual labor and tools within the energy limits of the best known farming system. This can be done by specializing in high-value crops or by diversifying to spread labor and resources over the entire year rather than concentrating it on a single crop or season. Farm planning and land use surveys can help farmers to plan adequately for coordinated use of their land, labor, capital and time resources.

1) Defining Characteristics of Hand-powered Agriculture

Accurate, detailed information about hand-farming systems is meager. Norman[40] and Gibbs[41] are making an intensive study of several groups of Nigerian villages to define the social, economic and agricultural factors of a cultural living unit and how it is influenced by outside as well as inside forces and contacts. CADU in Ethiopia is making a detailed study of hand- and animal-powered agriculture in Chilalo Awraja as part of an overall package development program.[42]

Educators, administrators and technical officials do not know enough about the small cultivator, his motivations and beliefs in life and agriculture. Without a detailed knowledge of existing cultivation practices evolved by African farmers through long experience, sound recommendations for changes cannot be made. Before any attempt is made to introduce innovations, the existing cultivation pattern must be sufficiently analyzed to define both its advantages and disadvantages.

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[40] David W. Norman, *An Economic Study of Three Villages in Zaria Province*, Samaru Miscellaneous Paper No. 19 (Samaru, Nigeria: Ahmadu Bello University, Institute for Agricultural Research, 1967).

[41] C.J.N. Gibbs, *An Economic Study of Three Villages in Bauchi Province*, Samaru Miscellaneous Paper (Samaru, Zaria: Ahmadu Bello University, August, 1968).

[42] Bengtsson, *op. cit.*

2) Lack of Adaptive Research and Locally Tested Innovations

There is a paucity of locally-tested innovations recommendable to the small farmer of limited resources. This lack of tried and proven techniques has caused the extension service and agricultural advisers to make serious mistakes in the past in trying to tell African farmers how to improve their practices. Many technicians lack actual farm experience and consequently cannot gain the farmers confidence. There is very little communication between the farmer and those responsible for planning and making decisions.

Too often the farmer has been left out. All national governments and regional bodies should become more aware of what is happening at the farm level and why farmers do some things and not others. The CENTO traveling seminars in Turkey, Pakistan, and Iran are a good example of regional activity designed to understand the farmer and his problems.[43] Many of the explanations they found for farmers not following recommendations or adopting improved practices would apply in Equatorial Africa.

Steps should be taken to provide a supply of hand-operated machinery and equipment for the small farmer since, for a long time to come, a substantial portion of African agricultural production will come from individuals who cannot afford to mechanize in any other way. Even if the traditional farmers are responsive to economic incentives, they do not search out new methods or inputs. Farmers' expectations must be changed; they must be alert, aspire and seek out new possibilities to improve their position.

3) Active Support of the Extension Service

In an attempt to promote better tools, the extension service of the Ministry of Agriculture must be an active and constant participant. First, there must be many good extension agents in regular contact with farmers. This in itself is a major problem in Equatorial Africa because of the scarcity of trained people and the shortage of funds allocated to the agricultural services. Secondly, extension agents must be convinced of the merits of the improved tools and practices they are demonstrating to farmers. Thirdly, they must get out into the field and work confidently with the farmer. To succeed, the improved tool must be an integral part of an overall program so the farmer accepts the tool as part of a package of improved farming practices. For example, to increase maize yields by more timely and efficient weeding with an improved hoe and row cultivation.

4) Local Supply and Repair of Tools

But simply developing tools is not enough -- the blacksmith must be taught

[43] Central Treaty Organization, *Traveling Seminar for Increased Agricultural Production*, 1962; *Traveling Seminar on Farm Tools and Implements, Iran, Pakistan, Turkey* (Ankara: CENTO, 1968), and others.

how to make and repair them. This can best be done by bringing him in for a special one or two-day school. Short intensive-training programs to teach one specific thing are an effective way to get across new ideas, with follow-up visits to the place of business. This is also just as true for farmers. As Rigter pointed out in northern Ghana, the follow-up farm visit is the most important part of the training program.[44]

Animal-powered Systems

Where cattle are a traditional part of the lives of farming people, it is easier to get farmers to consider the use of animals as a power source since they are experienced in handling and caring for them. There are many instances, however, in which cattle herding and established cultivation traditionally are not combined. Cattle herders are more reluctant to become farmers than hand-farmers are to adopt animals for power. This situation exists in parts of Ethiopia, Kenya, Tanzania, Nigeria, Ghana, and Senegal.

Wherever trypanosomiasis and other serious diseases have prevented cattle raising, farmers have been forced to farm by hand. In these areas, as soon as the disease problem is minimized, the whole concept of animal use and care can be introduced along with the techniques of handling and harnessing of animals. At the same time, improved cultivation practices must be introduced to permit the efficient and profitable use of animal-powered tools.

In French-speaking western Africa, comparatively few mechanized schemes operate outside of large-scale export-oriented plantations and farms. One scheme in the Central African Republic is reported to be quite successful: tractors for the heavy breaking, clearing and leveling; ox plows for planting and cultivating; and hand-work for the remaining tasks are used because there are few draft animals in the region.[45] In other parts of Francophone western Africa, the accent is mainly on animal-drawn equipment. Even with animal power mechanization is profitable only when applied to export crops.

Considerably more emphasis has been placed on the utilization of improved animal-drawn implements during the past decade in western Africa than in eastern Africa. Senegal has made the most progress, supported by a quasi-government organization, Société Industrelle Sénégalaise de Constructions Méchaniques et de Matériels Agricoles (SISCOMA), to produce improved tools and implements. All extension recommendations are backed up by a long-term intensive experimentation and research program at the Bambey Centre for Agronomic

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[44] Karel Rigter, Agricultural Missionary, Christian Service Committee, Garu, northeastern Ghana, Personal Communication, November, 1968.

[45] C.S. Gordon, AID Operations Officer, Bongui, Central African Republic, Personal Communication, January, 1968.

Research. The Bambey Centre has made many studies on practical aspects of agricultural mechanization and has developed, tested and approved implements for the emerging commercial-minded small farmer.[46]

Much of the success of Senegal's increased agricultural productivity results from the formation and training of a large field staff of so-called "popularizers" who work closely with the Bambey Centre and take the improved practices and equipment to the farmers. They work intensively with each farmer, help him apply a whole package of ideas and improved inputs, according to his specific local conditions and present stage of development.

Increased power and improved tools are an important part of this program, but it must be noted, the tools are made a part of an improved farming practice and are necessary to put it into effect. Each tool has a specific purpose and is designed for multi-use. Plowing and deep placement of fertilizer demonstrate how animal-power and a fertilizer unit made the production of groundnuts commercially feasible. In addition, each new practice is thoroughly tested on farms and in pilot projects before being promoted on a large scale.

Such a program of research and promotion for farmers is a gigantic task for any developing country. The large number of men and resources used by Senegal in implementing the current program to increase groundnut and millet production are cited in Part Two, Chapter V. It is a tremendous job to introduce proven techniques with new power and associated tools at the farm level. If this is true for the relatively simple animal-powered system, how much more difficult it is to teach hand-farmers with low education levels and skills all the fundamentals of advanced engine-powered systems.

1) Limitations and Constraints

Some limitations and bottlenecks affecting the use of animal-power are:

a) <u>Cultivation Practices</u> Simplified methods of seedbed preparation in Ethiopia for peas and flax with indigenous breaking plows often result in poor yields. Fields so planted are plowed only once and Bengtsson says this method explains the heavy weed infestation in these crops.[47]

To prepare a reasonably weed-free seedbed with the native ox-drawn breaking *ard*, the Ethiopian farmer must plow the land three to four times. This takes a tremendous amount of time, and Bengtsson's study showed a single farmer cultivating about 8 ha. spends about 390 hours plowing, if he does all the work alone. Since no work is carried out on holidays or Sundays, the plowing takes two months.[48]

[46] M. Monnier, Chief Technical Research Officer, Mechanization, Bambey Centre for Agronomic Research, Thies, Senegal, Personal Communication, July, 1968.

[47] Bengtsson, *op. cit.*, p. 6.

[48] *Ibid.*, p. 9.

Nor is broadcast seed by ox-plowing efficient. It not only takes considerable time, but covers much of the seed too deeply or not enough. Bengtsson suggests this practice explains the excessive seed rates used.[49]

b) Weed and Management Problems Plowing practices of farmers in central Ethiopia are restricted by tool, weather and management limitations. All plowing is carried out with the simple ox-plow with a bent wooden beam and a small iron point. It is inefficient, breaking open only the surface of the soil and lacks turning properties. Weed growth is checked very little and many farmers regard plowing as just a means of seedbed preparation. Although farmers admit they have many weeds in their fields, only one-fifth of them regard plowing as a weed control method. Hand-picking or cutting of tall weeds is seldom carried out between plowings.[50]

To facilitate the work of the oxen-pulled plow, most plowing is carried out according to the rains. Ninety percent of farmers start to prepare the soil when it is moist enough or after approximately one week of rain. Nevertheless, the remaining 10 percent say they do not need rain in order to start plowing after harvest.[51]

c) Condition of Animals The condition and strength of oxen have a major effect on the depth and quality of land preparation. After the long dry season the oxen are in their poorest condition, when they need the most strength for the first plowing. If soil preparation for certain crops must begin while the ground is still dry and hard, the amount of land that can be prepared will be limited, the depth restricted and the farmer may be forced to plant other crops.

The poor condition of draft-animals, fed on bruised straw during the dry season, may be a major obstacle to improved animal cultivation using improved implements. This restraint could be eliminated if natural grasses now growing in many of those areas were cut while still green with the scythe or some other improved tool, and made into hay to provide food for the animals during the dry season. Straw bruising would lose the importance it now has for animal feed and allow the adoption of improved threshing methods and machines.

Care should be taken to develop better draft animals rather than to modify implements to fit poor power sources. In many instances, better feeding and care of existing draft animals can be complemented by improved yokes and harness and adequate organization of the field work.

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[49] *Ibid.*, p. 7.
[50] *Ibid.*, p. 5.
[51] *Ibid.*

d) <u>Tropical Diseases of Livestock</u> In the tropics disease is a major constraint. Large parts of Africa south of the Sahara have a particular problem caused by the tsetse fly. Winter and others point out that the tsetse fly prefers shaded areas in the forest or bush. While it will go out to feed on animals in the open, it usually attacks animals when they come into the shade to rest. It occurs in areas up to 1,840 meters elevation at the equator, but usually avoids areas with less than 76 cm. of rainfall.[52]

Trypanosomiasis is the common name given to a group of diseases of animals and man transmitted by the tsetse fly and usually fatal to horses, mules and donkeys. Tsetse also carries the infectious disease called sleeping sickness in man. Tsetse flies can be controlled by clearing trees and bush completely or selectively. It prefers tall trees over three meters high with dark bark, and usually rests below the two-meter level. The small farmer can protect his animals by providing suitable shade for them in clearings away from the forest or high bush. Other serious diseases are rinderpest, contagious bovine pleuro-pneumonia and east coast fever.

e) <u>Land Tenure</u> Most forms of non-owned land tenure tend to discourage the optimum use of resources. Theoretically, the exception is owner occupancy but even this form of land husbandry has disadvantages. So much of the small farmer's capital is locked up in his property that he is usually short of working capital. The owner-occupier is forced to farm at a low intensity or rely heavily on loans to finance his operations. In Ethiopia, Leander found none of such farmers heavily indebted.[53]

Where sharecropping is practiced, the basis for payment tends to discourage the optimum use of resources, particularly purchased inputs. Tenants share no concern about optimum combinations of resources for maximum profit from the land; they want to maximize their own returns for labor. Leander observed this occurs when tenant's marginal costs equal one-half to two-thirds of the total marginal returns. Therefore, the application of labor and capital to land is less intensive than under owner-occupancy.[54] One important conclusion may be drawn: sharecropping coupled with limited operational resources has an adverse effect on the intensity of production and upon the farmer's incentive.

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[52] J.J. Winter, *The Introduction of Farm Power for Increased Agricultural Production on Small Farms in Tropical Africa* (unpublished M.S. thesis) (Ithaca: Cornell University, 1966), pp. 44-48.

[53] Lars Leander, *A Case Study of Peasant Farming in the Digelu and Yeloma Areas, Chilalo Awraja, Ethiopia,* Publication No. 22 (mimeographed) (Addis Ababa: Chilalo Agricultural Development Unit, Swedish International Development Agency, January, 1969), p. 94.

[54] *Ibid.*

f) <u>Acceptance of Improved Tools or Techniques</u> Another limitation concerns the willingness of farmers to adopt new ideas and tools. Often, they do not know about improved tools but sometimes they have not been convinced of advantages over present tools or methods. Haynes mentions a case in northern Nigeria in which implements had been tested and recommended to farmers but were not accepted. The introduction of new implements has not proved easy in the past. Three examples of satisfactory implements not adopted by farmers are:

1. Rhino Cultivator. It had been found possible to control weeds with the cultivator, coupled with reridging at Samaru as long ago as 1954. The Rhino was on the standardization list by 1957 but few were sold. It is no longer available.

2. Super Eco Seeder. Tested in 1957 and manufactured in Kano, the high price of $70.00 probably prevented sales of this drill.

3. Annular groundnut-lifter. Tested in Kano and recommended in the provincial newsletter for local conditions; few, if any, were sold.

Haynes says the lack of published information and effective promotion was a major factor limiting adoption.[55]

g) <u>Effect of Intensive Cultivation on Land Erosion</u> Soil and water erosion are serious problems in Equatorial Africa. High intensity rainfall, steep slopes, erosive soils, rapid decay of organic matter, arid conditions for part of the year, over-grazing and intensive cultivation all contribute to damage to soils. The use of improved animal-tools and increased power make it possible to farm more land, to cultivate it more deeply, to pulverize it and to expose it to erosive elements. As Hopfen points out, in arid zones where organic matter decays rapidly, the humus in the soil is practically non-existent. Under such conditions the top soil turns into a crust during heavy rainfall or irrigation and impedes soil aeration and plant growth. Heavy soils when tilled have to be left in a cloddy condition. In tropical rain-fed regions good tilth is best maintained by a cover of natural vegetation.[56]

The prevention of erosion by suitable cultivation practices depends to a great extent upon the pattern of the rainfall. In some areas the early storms, just before or after planting, are more intense than during the later rains when an adequate ground cover has been established. Haynes stated that flat planting on broadlands appears to be unduly risky in such areas. The practice of planting on the flat to reduce seeding and initial weeding problems, and subsequently ridging-up the crop during cultivation is well-suited to areas

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[55] D.W.M. Haynes, *Ox-drawn Implements* (mimeographed) (Samaru, Zaria, Nigeria: Papers on Agricultural Engineering in Northern Nigeria, Ahmadu Bello University, 1964), p. 6.

[56] H.J. Hopfen, *Farm Implements in Arid and Tropical Regions*, (Rome: Food and Agricultural Organization of the United Nations, 1960), p. 62.

where the early rains normally are not intense and for crops which do not provide good cover. Tied or alternately tied ridges laid out by the string method to impound water may be the safest form of cultivation where early rainstorms are intense or unpredictable, or where expected rainfall exceeds the infiltration rate of the soil.[57]

2) Need for Improved Animal Tools and Practices

The traditional animal-powered farmer has been farming with tools and methods unchanged for centuries. The breaking-plow or *ard* is still the most widespread animal-drawn implement in northern and eastern Africa. Different types in use today are strikingly similar to the most ancient of *ards* illustrated on old Sumerian seal cylinders.[58]

a) Better Land Preparation In Ethiopia, Kenya, Ghana and Senegal, as well as in most parts of Equatorial Africa, there is need for improved plowing and seedbed preparation. With animal power the soil surface is only scratched by the plow and there is little weed control. Field investigations of the plowing depth show only 12-15 cm. as an average. This can be deepened by a more efficient plow requested by a majority of farmers. Another simple innovation would be a leveling implement to get an acceptable seedbed.[59]

Caution must be exercised in selecting and modifying implements, however, for different soil and rainfall characteristics. The breaking-plow is very suitable for semi-arid tropical zones where cereals, oil seeds and legumes are grown in soil moistened by seasonal rains. In sandy soils and under dry conditions, it has the advantage of leaving a trash layer on the surface without uprooting perennial plants, thus preventing excessive wind erosion and soil drifting. Attempts are being made to further improve the *ard* breaking-plow in semi-arid zones, instead of substituting the moldboard plow for it.

b) Better Training The proper control and utilization of animals for power depends upon good training and harnessing. In areas where animals are not commonly used for draft work, or where cattle herding and livestock farming are not traditional, both the farmers and the animals need to be trained. In Gambia, Senegal, Niger, Tanzania and Kenya, special ox-plowing schools were established in the late 1950's and early 1960's, although some in Ghana and Nigeria date back to the 1930's.

With independence, rising expectations and political promises favored tractor mechanization and many countries de-emphasized animal power and lost interest in ox-plowing. In Gambia, Niger and Senegal, the animal training

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[57] Haynes, *Ox-drawn Implements*, p. 18.

[58] Hopfen, *op. cit.*, p. 44.

[59] Bengtsson, *op. cit.*, p. 58.

schools have been largely inactive, but now there is interest in re-establishing or opening new schools in Ghana, Nigeria, Tanzania and Ethiopia. Tanzania favors a mobile ox-training unit, instead of a fixed school, to go directly to the farmer to avoid subjecting his oxen to possible disease at a permanent center.

Regardless of the approach, if hand-farmers are to be encouraged to use animal power efficiently and economically, they must receive special training and guidance in this technique. Animals must be carefully selected and trained, properly cared for and fed, and fully utilized. The extension service, loaning agency, veterinary service, machinery suppliers and training schools must all have a part in developing and conducting the educational program, the implementation program and the follow-up program on the farmer's land. As an example, Braun recommended a system for the purchase of oxen and training of animals and farmers.[60]

c) Better Farming Practices To justify any increased investment in improved tools, power and inputs, the animal-powered farmer must be a more efficient producer. As Cooper emphasizes,

> An extremely high-standard of farming must complement the high cost of mechanization. In terms of relative productivity [emergent mechanized farmers] must be 2 1/2 to 3 times higher than the unskilled farmer.[61]

The acquisition of more land or the acceptance of responsibility for working or cultivating additional land imposes new problems on the emerging farmer already faced with finding new or better use of his new power capability. In developing new implements for Nigerian farmers, Haynes mentions some stumbling blocks encountered by African farmers:[62]

1. Mechanization commonly brings about a reduction in yield but a marked increase in output per worker per hectare. It is essentially extensive and usually applied to cash crops. One factor common to subsistence and cash crop farmers is low productivity.

2. The animal plow-farmer in most cases is still dependent upon hand labor for planting, weeding and harvesting so he may not be able to reach the full potential of his improved implements and power.

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[60] H.J. Braun, *Niger*, Agricultural Progress Report No. 8 (Rome: Food and Agricultural Organization of the United Nations, 1964).

[61] S.G.C. Cooper, *Report on a Visit to Uganda, Zambia and Tanzania, April 3 - May 6, 1966*, (mimeographed) (Nairobi: Common Services Organization, Agricultural Services, 1966), p. 22.

[62] D.W.M. Haynes, *Samaru Research Bulletin No. 65* (Zaria, Nigeria: Ahmadu Bello University, Institute for Agricultural Research, 1965).

3. The management problem can be reduced by providing implements which reduce peak labor requirements to a common level.

4. A simple weeder is needed to supplement the existing plow. Although weeding is not the most labor-consuming task, first weeding of cash crops coincides with cultivation and planting of late crops, creating a labor shortage which can be a major constraint.

5. Simple implements are needed for harvesting, since it demands more labor than weeding. In areas where soils dry out rapidly after rains cease, farmers have difficulty digging groundnuts. A groundnut lifter is a third improved tool needed by the (Nigerian) animal-powered farmer.

6. Multi-purpose implements are intended for new mixed-farmers who lack plows with attachments for tie-ridging, dry ridge-splitting, weeding and lifting. The farmer can expand his operations with little additional investment.

d) Supporting Services Once the subsistence farmer begins to produce for market and to purchase inputs to increase his productivity, he becomes less self-sufficient and more dependent upon the help and supplies of outside sources. In changing to animal-power, or in improving present ability to utilize it, the farmer needs to know what he can do for himself and what is best done by others. Winter suggests new services, supplies and assistance are needed to complement improved animal-power capability.[63]

1. Farmers need a source for better harnesses and yokes, and advice on correct fitting and hitching.

2. They need access to harness repair shops and local craftsmen who utilize the best available materials.

3. A government veterinary service is necessary for the prevention of disease and for vaccinations, including dipping facilities.

4. A source of salves and medicine for disease and parasite control must be available, sold by people who know how to prescribe and administer them.

5. A blacksmith with new skills is needed in the local village to maintain and sharpen equipment and to produce replacement parts.

6. The extension service must provide training schools or short courses for local businessmen on modern agricultural practices and needs.

7. The small farmer must have local support sources since he cannot afford to depend on a supplier in some distant city.

For all present hand- and animal-powered farmers in Equatorial Africa, much can be done to improve farming ability by increasing their knowledge of the basic sciences of agriculture. This can be done by helping them to develop new skills, by providing essential government services beyond the limits

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[63] Winter, *op. cit.*, pp. 96-102.

of their own resources, by creating favorable markets and incentives and by considering their needs and wants. In summary, Fischer suggests a policy of mechanization in Ethiopia that could apply to all of Equatorial Africa.

> . . . Guided mechanization, including the introduction of improved hand tools and animal-drawn equipment, represents a feasible opportunity to achieve significant results. One problem is that of capital. It requires a monetary input few Ethiopian farmers have available. Ways must be found to finance the purchase of machines. Likewise, facilities and manpower for maintaining equipment are inadequate. Service of the type taken for granted in a developed country is unavailable . . . Ethiopian farmers have had almost no experience with mechanized equipment. Cooperative machinery pools or maintenance stations may help solve many of the problems.[64]

Engine-powered Systems

There is much evidence to show that jobs such as seedbed preparation, general cultivation, plant protection, harvesting, threshing, water-pumping and land reclamation can be done more efficiently and with greater productivity by using tractors and engine-powered machinery rather than traditional hand-operated or animal-drawn implements. The question is not whether engine-powered machines are to be introduced into the agriculture of Equatorial Africa, but rather the nature, degree and pace at which they can be introduced to maintain economic efficiency in the farming system without causing serious social disruption.

Gradual and selective mechanization fitted to the needs and resources of each country will permit the necessary time-lag for sufficient progress to be made in development of small local industries. Surplus farm labor then can be absorbed into new and more attractive employment. When mechanization is chosen to complement, it also creates new labor opportunities in agriculture by bringing new land into production and by increasing overall crop production and yields.

1) Obstacles to Mechanization

Among the many problems in introducing tractors and other engine-powered machinery into Equatorial Africa, one of the most troublesome is the small-sized holdings of individual farmers. This problem is aggravated by extreme fragmentation of holdings into odd-shaped, individual plots where it is difficult to operate larger engine-powered equipment efficiently and economically. Frequently, there is no access to individual plots and many areas are not properly cleared or drained.

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[64] J.L. Fischer, *Ethiopia: Its Agriculture, Plans and Major Issues* (mimeographed) (Addis Ababa: USAID/Ethiopia, May, 1967), p. 61.

Another obstacle to mechanization is the high initial cost of machinery beyond the means of all but a few farmers. This is directly related to the lack of credit facilities in rural areas. Inadequate service and repair facilities in local communities, limited centers for the distribution of supplies, and intermittent seasonal working periods all contribute to higher hourly costs of operation. Inadequate or non-existent facilities for the maintenance and the manufacture of spare parts is another major problem. There is also a scarcity of trained technicians and skilled operators to service, overhaul and operate all types of engine-powered machinery.

The overall picture is one of continual struggle against rising costs. Whatever form of mechanization is adopted, it is apparent that the power-farmer will have to be efficient if he is to survive. He will need to use every possible means to raise his yields per unit area to cover increased costs. The target, as Haynes emphasizes,

> must be mechanized farming -- an integrated system of machines to increase productivity of the men and good farming to increase the return from Northern Nigeria's resources and to conserve these resources for the future.[65]

A broad view of various forms of engine-powered systems and the complementary tools has been presented. How they can best be utilized to assist the African as well as the expatriate farmer in advancing farming practices and developing a viable agricultural economy is a problem facing all developing countries.

2) Contract Hire Services

In establishing a contracting tractor-hire service, improper selection and application of machinery must be avoided. There has been insufficient experience with machines and machine systems under varying local conditions. Time is needed to test and evaluate equipment. Adequate funds and personnel are essential to carry out field trials and do adaptive research. The availability of equipment has been limited, and often purchases are tied to the source of finance. Furthermore, the lack of adequate and competent personnel to supervise field operations is a serious handicap. Due respect for the care of tractors and machinery will come only with thorough control provided by adequate supervision.

Long-range economic development of mechanized agriculture demands a systematic approach to selection, application, use and maintenance of tractors and machinery. Integrated machine cultivation practice trials in the field should be an integral part of all accelerated programs to increase crop production.

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[65] D.W.M. Haynes, *Papers on Agricultural Engineering in Northern Nigeria* (Zaria, Nigeria: Ahmadu Bello University, Institute for Agricultural Research, 1964), Sec. III, p. 14.

In evaluating tractor-hire services Downing points out, "the density of blocks is more important than the size of the fields."[66] In areas farmed by small farmers, he recommends a density of at least 60 hectares in a 1.6 kilometer radius with a minimum field size of 1.6 hectares. Smaller plots can be cultivated economically by medium-size tractors provided, the plots are dense and regular in shape. For extensive cultivation as found in the Masai Wheat Scheme, a minimum field size of 80 hectares, or a total of 200 hectares within a 3.2 kilometer radius is suggested. The fields must have reasonable access to avoid high operation costs and unprofitable delays.

To achieve any degree of efficiency in contract work, all field operations must be planned in advance for maximum utilization of the existing capacity of equipment and men. Fields must be laid out to reduce idle time in turning on the ends, in maneuvering around obstructions and in wasting time trying to define field boundaries. The block fields must be in regular rectangular strips for greatest efficiency. The farmer or manager must be on the site during the performance of the work to give necessary assistance, to approve the quality of work and to certify the time taken on which all hourly charges are based.

Adequate clearing for mechanized operations is seldom done unless the contractor insists. Trees, bushes, stones and excessive trash should be satisfactorily removed. Any obstruction which remains must be c[illegible]y marked and pointed out by the farmer. Land improperly cleared should be bypassed.

a) Organization for Contract Service The same factors which make the operation of a government hire service necessary also make its long-term economic operation very unlikely. Government service cannot be based on purely economic factors but must weigh the subsidiary benefits against the direct financial cost and any reasonable loss which may occur. The biggest problems are generally personnel, organization and management. Downing states:

> Experience has shown that the primary pitfall stems from the tendency to extend such a service beyond the capacity to organize and manage. [They have found in Kenya that] 50 units is within their capacity to provide reasonable management under difficult logistic and communication systems which exist in developing countries. Should a larger service be required . . . it would have to be on a regional basis consisting of smaller autonomous units.[67]

Additional units should be created to absorb excess demand generated by a well-run original organization and not simply based on arbitrary estimate. A government should start with reasonable sized pilot projects. When these

[66] C.M. Downing, *Tractor Hire Service Report and Evaluation - Financial Year 1966-67*, (mimeographed) (Nairobi: Ministry of Agriculture, 1968), p. 4.

[67] *Ibid.*, p. 3.

have been successfully implemented, new projects can be started in adjacent areas where sufficient demand has been built up and the farmers' confidence has been gained. Experienced personnel can be taken from the original project to form a cadre for the new unit. This also would provide opportunity for advancing qualified personnel to more responsible positions.

b) Incentives for Contract Hire Employees One of the greatest obstacles to increased productivity is the absence of mobility and incentive within the government wage structure. In Kenya, there are only two classifications of field staff, tractor driver and contract supervisor.[68] With the tractor-driver's position and wages fixed, and with such a large gap between them and their supervisors', there is no way to provide incentives to drivers who do a better job. Emphasis today is placed on obtaining a road license and not upon the ability to operate a tractor and its implements in the field. The same problem exists in government hire services in Ghana, Nigeria and Tanzania. In place of the present single grade of tractor-driver, Downing proposes a five-step employee classification to provide for merit advancement and increased efficiency.

1. Farm machinery operator trainee: salary $252 per year;
2. Farm machinery operator: salary from $456 to $700 per year;
3. Senior farm machinery operator: salary $661 to $896 per year;
4. Farm machinery technician: salary $840 to $1,232 per year;
5. Farm machinery manager: salary from $1,960 to $2,970 per year.

Other forms of incentive pay also may be used to increase operator efficiency and machinery care. Starnes, in Ghana, suggested a flat base pay of $0.65 per day for tractor operators and a bonus of $0.25 for each hectare cultivated. Each operator would submit his work record through the supervisor and collect the bonus on every hectare of work each month. The accumulated bonus would be divided equally among operators and mechanics, and adjustments would be made for time off and lack of attendance.[69]

3) Servicing and Repairing Machinery

Implements and machines differ from the majority of farm supplies in that their sales imply and require a continuing commitment on the part of the seller to provide spare parts and service for many years after the original purchase. Although the situation differs widely from place to place, the high cost and difficulty of servicing and repairing machinery are of

[68] *Ibid.*, p. 4.

[69] Max Starnes, USAID Machinery Advisor, Accra, Ghana, Personal Communication, November, 1968.

general concern throughout Equatorial Africa. Costs and short supplies affect hand and animal tools as much as engine-powered equipment; frequently it is more difficult to get repairs for a hand-decorticator than for a tractor. The difficulty of obtaining adequate service is often cited as a limiting factor in the expansion of mechanization at all levels.

Neither the government nor the main distributor can be expected to wholly provide the broad network of service facilities which will be needed as mechanization expands into small rural communities. Only a village farm-equipment specialist can hope to provide the service needed in rural areas. Governments must take responsibility to determine how village blacksmiths, artisans and others can be trained, established and supplied to alleviate this serious problem.

4) Standardization of Machinery

The decision to buy a single make of tractor is not necessarily valid because the rapidity of model changes necessitates stocking large numbers of spare parts and giving specialized training to operators and mechanics. Furthermore, tractor standardization prevents desirable competition among agents and may reduce after-sales service and technical assistance. While standardization can be controlled by legislation banning imports or imposing restrictive tariffs on unapproved brands, this type of control can slow development. Adequate control can probably be achieved by voluntary testing and approval, and by restricting the granting of loans to specified types or makes of machinery supported by proven and demonstrated service and training programs.

The establishment of an implement factory should not necessarily mean the imposition of protective tariffs. Experience in Asia and other areas shows that such industry often produces machinery which is even more expensive than imported models. Overly protected locally-made equipment is often inferior in quality and needs healthy competition to force improvements and to reduce costs; otherwise mechanization is retarded.

Some countries have standardized on one make of wheel-tractor and have experienced great difficulty in obtaining spare parts and in keeping the units in good repair. Rational selection is the best form of standardization and includes these considerations:

1. The restriction of purchases to two or three competing makes, so that sufficient volume of sales will enable responsible agents to supply efficient and complete service for their machinery;

2. All implement linkage specifications standardized, including characteristics of hydraulic lifts, so that implements can be used with different models and makes of power units;

3. Within any given region or project underwritten by a government, the

same model of tractor be used, insofar as possible, to facilitate repair, stockage of parts and training of operators. Ol r tractors can be reassigned to concentrate them for more efficient utilization and management.

5) Testing and Evaluation of Machinery

There is urgent need for adaptive research to select, modify, redesign, field test and issue unbiased reports on the suitability and performance of agricultural machinery. Planning staffs in ministries, teaching and advisory groups and extension agents all require advice on the technical and economic suitability of new, improved and competing types of equipment. Facilities connected with the universities are probably the most suitable sites for testing and comparing implements. However, no university should be expected to involve itself in adjudicating the merits of different commercial equipment.

For effective testing and consistent standards supported by adequate staff and funds, such research centers should be limited to larger countries and should perform work for regions of similar ecological and cropping programs. There is no need to duplicate large tractor performance tests made by the University of Nebraska, the National Institute of Agricultural Engineering or similar bodies. The true costs of using tractors and machinery should be determined for specific systems and reliable recommendations made available to farmers through informed extension agents.

The working party of agricultural engineers in Nigeria suggested that agricultural engineers in developing countries should undertake:[70]

1. The adaption of machines to specific conditions;
2. Comparisons of mechanical methods;
3. Development of methods of soil amelioration and conservation;
4. Investigations to determine cost and efficiency;
5. Specific recommendations for selective mechanization of local projects and activities.

An Economic Analysis

Analytical Approach to Farm Systems

The cases which have been described form the basis for analyzing what changes are likely to occur as new forms of mechanization are introduced into established systems, and to discern factors which favor or limit this process. Mechanization may be used as an analytical concept by categorizing forms of mechanical assistance into hand-, animal-, and engine-powered farming. These three categories, when transferred into the dynamic process of economic development broaden into six manifestations:

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[70] Haynes, *Papers on Agricultural Engineering in Northern Nigeria*, p. 10.

1. Three processes of improvement: in hand-powered implements, in animal-powered, and in engine-powered implements; and

2. Three processes of transition: from hand-powered to animal-powered technology, from animal-powered to engine-powered technology, and from hand-powered directly to engine-powered technology. (A reversal of the process is also possible.)

An important principle in the analysis of agricultural mechanization is that of appropriateness. The case for reverting from tractor power to oxen illustrates this principle. Following a careful analysis, the Tanzanian government has concluded that engine-powered technology was inappropriate to the current level of development in most of the economy. Thus, it should not be assumed that there is a natural sequence from hand power through animal power to engine power. There are situations where conditions are appropriate to eliminate the animal power stage by moving directly from hand- to engine-powered technology. In other situations no shift is appropriate. Thus, forms of power cannot be arbitrarily related to levels of economic development. Rather, the developing economy should attempt to realize optimal returns from total available resources, employing levels of power appropriate to the economic situation.

General Economic Considerations in the Introduction of Mechanized Agricultural Technology

The following considerations are relevant to an analysis of both animal and engine-powered systems to determine the level of mechanization most appropriate to an economic situation and its likely impact on the local and national economy:

1. The level of mechanization already achieved in the system;
2. The level of management skill necessary to maintain the established level of mechanization, and in order to achieve a possible new level;
3. The function of innovation and entrepreneurship;
4. The economies of scale currently being experienced and potential economies;
5. Infrastructure to develop a commercial economy;
6. Export potential to domestic and world markets;
7. Impact of the operation on the local economy;
8. Scope for new forms of mechanization.

In all the systems under observation it is essential to consider market outlets for surplus production. Mechanization has as its major objective the improvement of agricultural productivity, and farmers become involved in production of surpluses which must meet the additional costs of mechanization.

Thus, the surplus must be saleable. Where effective demand is inadequate, programs to introduce a new form of mechanized technology should not be implemented.

Hand-powered Agriculture

An analysis of hand-powered farming systems with a view to introducing a mechanized agricultural technology must give careful attention in the extant systems to the level and scope for mechanization, innovation and entrepreneurial activities, and infrastructure. However, in addition to considering the potentials of mechanization within the established system, it is important to consider the potential for introducing an outside commercial enterprise to act as an economic catalyst. A large commercial enterprise can facilitate the establishment of market infrastructure, especially if its introduction is conceived as part of a larger plan developed in cooperation with national economic planners.

Animal-powered Agriculture

Economic considerations relevant to animal-powered agriculture are similar to those for engine-powered agriculture with the exception of the level of employment which is no longer meaningful because animal power operates in the framework of small family farms. Other factors that must be considered are: low-cost structure of animal-powered operations, and low cost to the national economy of introducing animal-powered technology involving little or no foreign exchange.

Settlements

Settlement schemes involve the additional social dimension of establishing people in new locations. The above considerations remain relevant and in addition it is important to consider the general economic framework into which the settlement must be integrated in order to market its produce, and the microeconomy of the settlement scheme itself.

Important economic considerations, for example, in the Tanzanian Block Mechanization Scheme are: appropriateness of the type of mechanization; management; economies of scale; the facilities for planning and training; the shift in cost structure; and substitution versus supplementation of hand labor.

Tractor-hire Services

Important factors of any tractor-hire service are: effectiveness of management; operational skills of drivers, operators and mechanics; and the importance of incorporation into an integrated program of mechanization.

Associated Social Considerations

In all these stages of analysis there are also associated social problems

relevant to the problem of agricultural mechanization. In the case of large-scale farming, the major social problem emerges out of the necessity to accommodate large numbers of migrant workers in temporary communities. The social problems of settlements are numerous and involve changes in the way of life of a group of people. Social problems created by the employment of tractors relate to a shift from uneducated skills to educated skills. The associated social problems emerging from hand-labor economies are related to the relative isolation of village communities; the suspicion shown toward farmers who tend to prosper excessively; the ties which people feel to a particular area of land; the lack of interest or traditional prejudices which many people show toward animal use and animal husbandry.

There is also an overriding social problem to be reckoned with throughout Africa: the conflict in loyalties between a man and his parent community on the one hand and the impersonal, rational demands of the market economy on the other. Until an aspect of social security has been built into the modern African economies, planners of economic development must recognize the fact that the final loyalties of most individuals involved have terms of reference which lie outside the ramifications of the program itself.

Introduction of Improved Technology and Power into Present Farming Systems

Engineering and Technical Appraisal

The factors which favor each level of mechanization and the gradual transition from one level to another are presented in Chapter V. No pure system of animal- or engine-power exists without hand-power. Frequently all three levels exist on the same farm; and they exist side by side in all countries in Equatorial Africa.

At this stage of development, more systematic and earnest attention needs to be focused on the needs of the emerging commercially-oriented hand- and animal-powered farmer. He can be assisted by the wise application of selected units of improved hand-, animal-, and engine-powered systems, to overcome traditional constraints and to eliminate bottlenecks as they develop in his intensification program. The tractor-hire service, either government or privately operated, can perform a very useful and beneficial service for developing farmers.

There are many ways of organizing resources for rational and selective introduction of improved agricultural power systems. Several methods of

introducing new technology to improve present systems of farming in Equatorial Africa are illustrated by case studies of successful projects implemented in western and eastern Africa. All of these projects are currently active and viable; and provide guidelines for further accelerated development of agriculture through selective mechanization.

Agricultural Intensification in Senegal

The biggest problem seems to be that governments are not fully committed to agricultural development, nor wholly convinced of its necessity. Before agriculture can undergo marked change it must be given top priority in the allocation of the countries' resources. In western Africa, Senegal shows what can be done with an intensification program aimed at converting the traditional hand-powered subsistence farmer into a market-oriented animal-powered farmer. This case also emphasizes the tremendous effort that must be made steadily and the magnitude of the needed resources. It is not easy nor inexpensive, but it pays high dividends if the right decisions are made.

The Motoragri Operation in Ivory Coast

The example offered by Motoragri of introducing rational engine-powered assistance to the entire agricultural and rural sector of a country shows how technical assistance can greatly accelerate a country's agricultural development on a businesslike basis. Three points are crucial to the successful organization and operation of such a venture:

1. If qualified staffs are not available, a competent team of foreign professional and technical people must be brought in to manage and be responsible for the operation with full authority and accountability for the project.

2. An intensive, objective, practical and continuing training program must be instituted from the start with full responsibility given to the organization to select and hire local employees, to discharge unsatisfactory personnel, and to assemble an effective skilled labor force.

3. Carefully kept records and cost accounting must make it possible to determine operation costs and to predict needs and progress accurately. Motoragri shows the results of planning, training, evaluation and accounting that are continuous and objective.

The Narosurra Farm Mechanization Training Scheme

Throughout all projects, the need for more thorough training is evident. There is a great deficiency in training tractor operators for government hire services, cooperatives, settlement schemes, group farms and other agricultural projects. Little attention is being given to training farmers and private contractors to be qualified operators. Need for this training exists at both the animal- and engine-powered levels.

An excellent example of practical, intensive training designed to aid more progressive farmers moving up the mechanization ladder to engine power is the Marosurra Farm Mechanization Training Scheme in Kenya. The Scheme conducts three 12-week courses per year, providing instruction in the operation and maintenance of agricultural machines, plowing, gas welding and simple repair work, farm accounting; and basic animal and crop husbandry. Each course takes 35 students, making a total of just over 100 each year. It represents an excellent method that needs adoption and extension in developing nations.

The trainees, in addition to their studies, undertake contract plowing and cultivating for farmers in the neighborhood The provision of this mechanization service, particularly in view of the area's marginal rainfall, greatly increases productivity and converts a semi-endemic famine area into a granary for Kenya Of greater importance, however, is the impact that graduates have on farming in their own areas. Most Marosurra graduates become either part-time or full-time contractors. They are setting new standards for work and efficiency. The Kenya government now requires, in fact, that all applicants for loans to purchase agricultural machinery and tractors be graduates of this type of training program. If all users and purchasers of small and large engine-powered systems were required to take similar training, it would speed the successful introduction of improved engine-powered systems in Equatorial Africa. Furthermore, it could greatly accelerate overall agricultural and national development.

Economic Appraisal

Improved technology implies improved productivity and thus, in the proper economic framework improved income for the producer Economic and technical factors operate in concert to increase agricultural income. The relative importance of each must be judged in the context of the developmental situation. Concomitant technical factors are related to the improvement of crop yields through fertilizer, improved varieties, weed and pest control and improved tillage practices

General Economic Framework

Programs designed to introduce changes in the level of mechanization must take into account the existing economic framework of the locality. The broad spectrum of economic consideration emphasizes the necessary areas of expenditure in a completely integrated program. The financial burden is likely to be heavy on sponsors, and may lead to a strong preference for concentrated programs of the package-deal approach. An integrated program of development implies integration at the micro-level of the locality: the level of mechanization is appropriate; all inputs must be readily available; and the soil and topography of the area have been taken fully into account. A program also must

be integrated at the macro-level with the national economy with adequate infrastructure to give market support to a new level of production, plans for a scheme become integrated with the overall plans of development for the nation.

At the micro-level of the local community a differentiated approach may appear most appropriate. Such a scheme must introduce a number of different levels of mechanization simultaneously, recognizing that not all farmers have equal understanding and skills. Furthermore, a large commercial enterprise in a locality can be incorporated into a differentiated plan, so that market infrastructure can be more rapidly developed for the entire area Such a commercial operation can be an economic catalyst where small farmers' abilities to mechanize are limited to improvements in hand tools and the introduction of some animal-powered implements.

Factors Favoring and Limiting the Introduction of Improved Technology and Mechanization into the Present Farming System

Mechanization schemes must meet added costs. In hand labor economies a major limitation to technological development is lack of monetization As the level of mechanization becomes more sophisticated, high management capacities become increasingly important, and an adequate infrastructure making modern inputs readily available becomes increasingly essential Where management skills are inadequate, some compensation can be effected through an efficient extension service and training facilities. Local adaptive research must be highly and consistently relevant to local problems especially in hand labor economies. The practice of multiple cropping in hand-powered farming keeps severe limitations on any form of mechanized technology Local prejudices, social preferences and attitudes frequently are found to be inhibitive, and must be recognized as relevant variables to the development plan.

Role of Mechanization in Agricultural Development

The role of mechanization in agricultural development is seen as the employment of additional capital in the production function either as a substitute for a factor of production or, in a neutral sense, to increase the total power employed in the production function without being a substitute for any factors. The addition of power only increases productivity in combination with other inputs, thus the role of mechanization must be seen in relation to the roles of other factors in the production function. In this context, mechanization is entitled to a special place in the order of priorities for developing systems of agriculture; the order of priorities for mechanization is frequently not first. Research and development facilities should emphasize priorities in the development in national plans of all sciences and disciplines relevant to agricultural development. Thus, in the Recommendations and Guidelines to follow, inquiry into mechanization is proposed to be maintained in close contact with other areas of agricultural inquiry.

RECOMMENDATIONS

Introduction

The principal objective of mechanization viewed in this Study, is to raise productivity in such a way that increased income will accrue to farming communities Agricultural mechanization is only one of many inputs contributing to agricultural productivity. Many economic interrelationships are involved in raising agricultural productivity and the economy must be maintained in dynamic equilibrium if increasing farm income is to be continuously realized. Research and development in aspects of agricultural engineering and mechanization for Equatorial Africa must be established in the context of the systems which prevail and must seek general agricultural improvement A balance between the interrelated areas of research must be maintained through coordination of technical and economic research

Recommendations are presented at two levels for the purposes of broad organizational planning to provide alternatives for coordinated research and development at the national level and to encourage regional cooperation at the international level A series of general guidelines is presented which relates to the planning of specific programs in particular areas, these are intended to assist in the local adaptation of recommendations made in general principle.

National agricultural research facilities are already established in all the African countries which have come within the compass of this Study. The recommendations are not intended to deal with details of their specific operations. Rather, it is recognized as an important feature of national independence that working out these details remains the province of national policy makers. Because of differing institutional structures and the necessity of firmly establishing agricultural development in the context of indigenous farm life, each nation's research organization must be unique In promoting research and development it is essential that existing facilities offer an adequate foundation on which to build an effective program and from which applied research can be effectively pursued It is believed that the governments in Equatorial Africa desire to promote rural development as rapidly as available resources permit. This attitude supports the introduction of more sophisticated forms of farm power and can lead to the adoption of national programs of agricultural mechanization. The Recommendations and Guidelines are presented to show how the experience gained from this Study can be utilized to develop local, national and international programs.

Recommendations I-X relate to the development of national policies, followed by Recommendation XI relating to international policy and Recommendation XII also having a regional basis. The guidelines which follow are

numerically aligned with the recommendations. The guidelines deal in greater detail with the subject matter of each recommendation to give more specific direction to policy development.

The Recommendations and Guidelines emphasize the complex interrelationships of economic, technical and social factors into which agricultural mechanization is injected as a further complication. Because of these complex interrelationships careful, long-term and short-range planning is essential to economic development "The full development of a country requires a multiplicity of institutions -- political, economic and social",[71] the creation of new institutions must be proposed circumspectly and created only when there is a clear function to be performed which cannot be performed by any other institution

In economic development "human resources development is the most critical need throughout the world",[72] and is most effectively achieved through the building of indigenous institutions. Until quite recently in the development of many African countries the establishment of educational and research institutions has been mainly on the basis of foreign concepts. Now these institutions are slowly being assimilated into the way of life of independent nations. This process is a natural one and with it inevitable modifications to the original concepts are taking place Fostering new institutions should be encouraged only on the basis of concepts engendered from within the socio-economic milieu of the nation, in contrast to being proposed and implemented by external agents, even though financial support may be mainly external.

Moreover, in making recommendations and guidelines designed to improve agricultural development through mechanization, planners must become involved in long-term processes Such planning necessitates long-term financial assistance, and the presence of competent and experienced professional personnel for protracted periods of service [73] Short-term service contracts and short-term financing are inadequate bases on which to build long-term plans of the nature envisaged in these recommendations

I. Recommendation to Strengthen National Research and Development Programs in Agricultural Power and Land Use

Appropriate research into agricultural power and land use should be encouraged in already established national institutions. These may be

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[71] Task Force on International Development Assistance and International Education, *International Development Assistance*, (National Association of State Universities and Land-Grant Colleges, January, 1969), Point 1.

[72] *Ibid.*, Point 2.

[73] *Ibid.*, Points 5 and 7.

universities, or institutes of agricultural research, or agricultural machine-testing centers depending on the way agricultural research has evolved within the individual countries. Thus, strengthening this area of work is most likely to take the form of financial support and coordinated direction to an operational research unit already in existence within a functioning institution.

It is important to recognise, however, that insufficient numbers of qualified personnel are available who are capable of organizing, managing, training and operating mechanized projects and performing skilled and highly technical tasks associated with the use, care, and repair of machines and tools.

In order to guide and implement the mechanisation of agriculture within a country, an overall national program of research and development is needed to define areas of responsibility, to develop broad concepts and to establish basic policies which will insure a well-planned and orderly treatment of all critical needs.

It is recommended that an appropriate national committee or other group of specialists be charged with the responsibility of developing a long-term agricultural mechanization program in terms of agricultural power and land use research and development The major responsibility of this body must be to coordinate the program, channel funds to the operational units, and insure efficient operation of the program

II Recommendation for a Program of Selective Mechanization of Small Farms

The majority of agricultural producers in Africa are small farmers, therefore, this sector of the economy deserves major attention in national policy-making. Mechanization is concerned with the productive processes of agriculture, but care must be taken not to overlook the importance of effective demand Hence, the proximity of a market or potential market is a vital consideration in drawing up any program to introduce mechanized technology to small farmers

In making this recommendation it is impossible to state unequivocally the type of mechanization programs to be pursued Environmental and socio-economic conditions of the small farmer vary greatly throughout Equatorial Africa; only in the full context of a particular system can an appropriate form of mechanisation be determined. Gradual evolution of farm power from hand-powered through animal-powered to engine-powered technology is frequently envisaged as a natural farm-power ladder of development. However, it is only possible to decide whether this evolutionary process is appropriate for the development of a country by careful analysis of the total relevant environment for which a program is to be planned. The key to development is the *appropriate* form of mechanisation in the given situation

Appropriate mechanization should facilitate the optimum utilization of economic resources Where there is widespread underemployment of labor, mechanization should not be of the labor-saving type The program should facilitate a general increase in effective local employment as well as the productivity of agricultural labor, and lead to increases in rural prosperity.

III Recommendation to Establish Facilities for the Improvement and Development of Small Tools and Implements

It is recommended that governments, through their appropriate ministries, coordinate and encourage endeavors to develop better tools and implements. This recommendation includes encouragement for the development of special implements powered by animals or small engines, and special incentives to individuals or groups to develop new ideas and improved tools for agriculture in tropical countries by making awards and/or granting patent-rights protection

A national awards program could be sponsored in two sections one for students, farmers and small shop operators, and another for professional engineers, designers and large shops or manufacturers Further encouragement in this area should take the following forms (1) good facilities for the importation of necessary steels, (2) standards of quality established and recognized by brand marks, (3) financial assistance and technical advice in the establishment of small workshops, (4) easy availability of plans and specifications for improved tools and implements, (It may be desirable to subject such equipment to a form of testing), (5) some form of supervised credit facilities for farmers interested in improved implements but who need training

IV Recommendation to Establish Farmers' Animal-power Training Facilities

Where animal power has been proved appropriate to the agricultural environment, there remains a major deficiency in the availability of suitable facilities for effectively teaching farmers more advanced farming practices. Facilities should be provided, they need not be elaborate and may be considered as appropriate adjuncts to established training institutes, but they must be properly organized and very practical The approach to training must be compatible with conditions that the farmer himself must face in improving his land, inputs of labor and power, and developing management skills. Fundamentals of better farming practices should be taught along with training in the use of animal power.

In any individual country, it is recommended that initially one national center be established as a pilot project in a centrally located area of high agricultural potential Other centers can be established using personnel and techniques developed at the first center as the success and need is proved.

V. Recommendation to Develop Facilities for Training in the Use of Farm Implements and Power Units

The adoption of improved farming practices including new forms of farm power generally depends upon the availability of improved tools which require well-trained and careful operators Such training also plays an important role in reducing repair and maintenance costs. It is recommended, therefore, that extension services be regarded as the most appropriate training medium for small farmers, and that extension agents be provided with adequate training in agricultural mechanization The training facilities can then be made available to farmers with adequate backgrounds to benefit from the experience.

Facilities for training both farmers and farm operators are generally inadequate. Moreover, very few training programs are designed with due recognition to the farmers' traditional background or level of literacy, their lack of disciplined organization, or their lack of training in mechanical arts. Often, extension workers are inadequately familiar with the farmers' way of life and have, themselves, insufficient knowledge about or proper training on improved mechanization tools and techniques

Again it should be emphasized that training facilities in these ar can be efficiently grafted onto the operational organization of already established institutions The burden of expensive administration can be avoided wherever an appropriate institution already is functioning

VI Recommendation to Supply Training Institutions with Adequate Funds and Equipment for Instruction in Agricultural Mechanization

Colleges, agricultural schools and training centers require basic and usable samples of modern tools, implements, equipment and tractors in order to give adequate instruction, field exercises and experiments. It is recommended, therefore, that joint cooperation between industrial and educational facilities be encouraged by the establishment of an appropriate joint-committee to arrange for such equipment to be made available Thus, teaching institutions would be able to keep modern equipment on hand without investing capital in obsolescent equipment.

The equipment could be made available on loan from manufacturers with suitable arrangements to underwrite repair and maintenance costs The cooperation of prominent machinery companies should be forthcoming because of the opportunity to establish good relationships with teaching institutions and students who are potential leaders in the future agricultural life of the country.

Distributors, dealers and manufacturers should be willing to provide current instructional literature and instructors. While it is important that

agricultural development in any one area should involve a strictly limited number of machinery makes, a cross-section of brands and models should be available within the training facilities

Finally, it is recommended that a reasonable portion of all funds granted to agricultural training facilities be allocated each year for acquisition of essential equipment and supplies, for expenses incurred in their operation, and the transportation of students to demonstration or experimental areas.

VII Recommendation to Develop Adequate Support in Repair and Maintenance Services

Parts and repair facilities for locally-made tools are generally available, being made from scrap metal and local timber Parts and repair facilities for imported or factory-made metal tools are less available in urban areas and unobtainable in rural areas

In most developing countries of Equatorial Africa, trained, experienced and skilled craftsmen are rarely found in rural areas Village blacksmiths and rural artisans are relatively few, and have the barest facilities and the simplest tools

Well-equipped machine shops and workshops in Equatorial Africa are for the most part in urban centers, owned and staffed largely by skilled expatriates Very few educated Africans are interested or qualified to own and operate such businesses Governments are frequently the largest purchasers of agricultural machinery, but they often by-pass any local dealer, or import machinery for which there is either no distributor or only a trading representative

Therefore, it is recommended that all government purchases of farm machinery be placed through an established importer with adequate facilities for services and stocks of spare parts If an importer is not already established, a new agent must agree to set up suitable repair and service facilities before a license is issued for the importation of machinery.

It is also recommended that governments carefully consider the advantages of permitting agricultural machinery and parts to be imported free of duty.

Further, in view of confusion which can arise in repair and maintenance services due to the multiplicity of types and models of agricultural equipment, particularly in areas using engine-powered agriculture, it is recommended that a policy be adopted to limit strictly the total number of makes and models of agricultural machines and power units that may be imported duty free A *machinery council* of qualified technical specialists should make these decisions, based preferably on a combination of proven performance records and on the willingness of manufacturers and importers to provide adequate supplies and spare parts, repair and maintenance services.

VIII. Recommendation to Establish Service Branches to Facilitate the Use of Mechanised Agricultural Technology

The national programs of research and development in farm power and land use can be gradually expanded as the agricultural technology of a country becomes more sophisticated. Operational branches of the main arm of the program may be desirable in several different parts of the country. In the context of a long-term machinery development plan, it is recommended that governments gradually establish extension and service branches in areas of high agricultural potential These branches must be staffed with properly trained extension workers and exist as functional units of the local extension service

Each branch should provide contract machinery-hire services for farmers, plantations and government bodies, assist private farmers in buying and efficiently using appropriate improved hand tools, oxen or tractors The branches should offer facilities in all aspects of agricultural mechanization and possibly conduct a limited amount of testing of machinery and implements.

IX Recommendation to Encourage Private Farm Mechanization and Private Ownership of Agricultural Machinery

Where private farmers are adequately trained or can obtain training, it is recommended that governments make funds available to facilitate the purchase of improved equipment Credit may be made available through a government agency with instructional and supervisory facilities so that farmers are guided in the use of both equipment and credit.

Equipment formerly owned by government machinery-hire services usually can be satisfactorily repaired for sale at reduced rates to private farmers. In the hands of trained private farmers, equipment can be operated on farms and on contract work with economic efficiency

Capital is available in the more prosperous families in developing countries. Landowners and professional members of families often help other family members by providing employment or purchasing capital equipment for them They probably would be willing to support a member of the family in private contracting business or in carrying out heavy work on a large family land-holding if this person were properly trained. It is recommended, therefore, that well-equipped schools, such as the Narosurra Farm Mechanization Training Scheme, be actively encouraged, and governments consider the advantages of establishing more schools of this type. In such institutions, potential private owners of equipment receive a thorough practical training Such training, coupled with adequate loan facilities will encourage agricultural mechanization in the private sector in which the profit motive is a more significant factor in farming operations than in government controlled undertakings.

X. Recommendation to Incorporate Large-scale Commercial Enterprises as Economic Catalysts in Rural Development Planning

Large-scale commercial operations can stimulate the development of local infrastructure which gradually orients smaller, less-mechanized agricultural systems in the area to a market economy A properly differentiated approach to rural development is needed to incorporate this catalytic function into development planning Several approaches to economic development at different levels of mechanization can be used appropriately and simultaneously in one area There must be a positive effort to promote the development of indigenous agricultural systems near any large-scale operation, otherwise, the two systems may merely coexist, and have little impact on each other

It is recommended, therefore, that rural development planners make serious efforts to incorporate the cooperation of commercial organizations This should include collaboration with private enterpreneurs through the inception, implementation, and operation of the plan

XI Recommendation to Coordinate Regional Research and Development in Agricultural Power and Land Use at the International Level

The Case

At a recent conference held in Abidjan,[74] delegates emphasized "the need for inter-disciplinary integration of research oriented to [the] project rather than specialization [oriented to the] discipline " In a follow-up speech on the conference activities[75] the need was stressed for:

> The establishment of an international center for agricultural equipment and mechanization [and a] study by a Ford Foundation team of the desirability and feasibility of some kind of center was recommended

Two additional excerpts from this speech are germane to coordinated regional research

> It was suggested that the more fundamental or basic oriented research lent itself better to international organizations along ecological lines, but that applied (adaptive) research fell more clearly within the province of national research institutions

> The more urgent need for work on soil surveys was felt to be the establishment of regional soil maps giving more details of soil family characteristics and their potential uses to farmers.

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[74] *Conference on Agricultural Research Priorities for Economic Development in Africa*, Abidjan, Ivory Coast, April 5-12, 1968 (Informal report to the Agency for International Development Debriefing Session, State Department, Washington, D C , May 21, 1968).

[75] Albert A Thornbrough, President, Massey-Ferguson, Limited, *View*, (speech to the 97th Annual General Meeting of the Canadian Manufacturers' Association, Halifax, Nova Scotia, June-July, 1968), pp. 16-18.

There appears a strong case for establishing and undergirding programs of national research and development, into which are incorporated programs in agricultural mechanization, and for regional cooperation between nations.[76] Furthermore, the political climate in countries of eastern and western Africa appears favorable to regional cooperation, with the establishment in December, 1967, of the East African Community and subsequent applications for membership from Burundi, Ethiopia, Somalia and Zambia; and several regional research centers having been established in western Africa, in both Anglophone and Francophone countries. However, caution must be exercised in promoting coordinated regional research Political precedences and support are already established, but time is required to implement the operational facilities. It is premature to propose another full-scale activity of regional cooperation, until currently existing regional institutions are functioning effectively in their delimited areas of operation

The recommendation to coordinate research and development in agricultural mechanization on a regional basis is made in two stages. The preliminary stage is the establishment of two *working groups* under the auspices of *councils of policy-makers* to investigate the operational details of acceptable programs, and the second stage is the implementation of the programs worked out in the first stage.

Working Groups

It is recommended that governments and private farm equipment organizations of interested "donor" countries and "recipient" African countries support the establishment of two *working groups* to investigate the feasibility and operation of the regional program.

Each *working group*, one to serve eastern and the other to serve western Africa, should consist of a multidisciplinary team including, at least, specialists in mechanization, agronomy, and agricultural economics, and possibly other related fields. The *working group* should perform under the auspices of a *council of policy-makers* representing each participating country. The eastern and western *working groups* should meet together as necessary to provide adequate liaison, and their function will be to draw up the administrative and technical details of an acceptable program to coordinate regional research in agricultural power and land use. The *working group* should deal mainly with technologists, scientists, and technical administrators from

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76". . . What is needed to lay the basis for solving the world's food problems, as I see it, is a network of good research institutions in the developing countries, of which international institutions are a part. In addition, there must be strong institutions in each country, locally managed and locally financed".
Ibid.

public and private sector of the economy to formulate into a plan the operational details of coordinated research and development. The primary function of the *council of policy-makers* should be to insure that the programs are politically acceptable to the participating countries, and that proper channels of communication are established with the appropriate ministries. The *council* may be attached to the Organization for African Unity (OAU) as an appropriate parent body, but fundings should be independent

The Programs

The recommendation to develop coordinated regional programs of research and development for agricultural power and land use is envisioned in three phases. The implementation of these phases will depend on both the level of funding available, the anticipated level of support to regional operations, and the details of the programs drawn up by the *working groups* Each program will inevitably require the establishment of a *regional coordinating unit.*

Regional Coordinating Units

Coordinated regional research and development is envisioned to be conducted mainly by specialists in national agricultural institutions with some work possibly being done by the staff of the *regional coordinating units* during the final phase of the program's development At each phase of a program, it will be necessary to have an *ad hoc* committee, a small secretariat agency, or a research unit to act as *regional coordinating unit.*

The function of these *regional coordinating units* follows after the findings of the *working group* have been completed and presented as an operational program. These functions should include the coordination of work in the following areas:

1. Designing, developing and adapting improved hand tools and animal implements,
2. Selecting and testing potentially suitable power units and large-scale machinery;
3. Conducting tillage research related to mechanized agriculture;
4. Selection and/or design of drying and processing equipment;
5. Promoting soil and land use surveys relevant to agricultural mechanization,
6. Recommending for development soils with the promise of greatest economic and social benefits.

Phase I: Specialist Committees as Regional Coordinating Units

It is recommended that the first phase of a regional program be the formation of a specialist committee meeting once or twice a year to exchange technical

information. Thus, the *regional coordinating unit* can be simply a committee requiring minimal funding.

This phase has been already established in EAAFRO. Additional funds can considerably strengthen the effectiveness of the specialist committee. In effect, the recommendation is one of expanding the specialist committee concept for eastern Africa and of developing a similar committee for western Africa, provided this is consistent with the mechanisation programs in the process of being developed.[77] It is recommended that the co-sponsors of the program be committed, in the first instance, to assist in providing salary and operating funds for a period of five years for a part-time executive secretary for each specialist's committee. Some of the duties of the executive secretary would be to plan and organize the specialist's meetings, arrange for recording and disseminating proceedings of each meeting, and coordinate the exchange of information between the eastern and western *units*.

In this way, all research and development work would be undertaken by national research institutions, while the *regional coordinating units* (*i.e.*, the specialist committees) guide the work and prevent duplication or wasted effort. The *regional coordinating units* would need operating bases which could be provided by the IITA in Nigeria for western Africa, and EAAFRO in Kenya for eastern Africa. Alternative locations for headquarters also should be investigated thoroughly by the *working groups* before any proposal to establish *regional coordinating units* is presented to the *council of policy-makers* for action.

Phase II. Secretariats as a Regional Coordinating Units

The second phase recommended is the establishment of a specific governmental agency or secretariat to stimulate needed research through contractual arrangements with existing national organizations. Again, it is recommended that the co-sponsors encourage the support of this form of *regional coordinating unit* in the first instance following on Phase I for a period of five years.

In this phase, each *regional coordinating unit* should be organized as a secretariat, with one or more full-time members to coordinate and stimulate research activity and exchange of information. It should have sufficient funds to contract for specific research projects on a matching basis with member countries. The national institutions should do the work, assisted financially by the *regional coordinating unit*. Interested researchers should be encouraged to submit proposals for specific projects to the *regional*

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[77] *Symposium of Farm Mechanization* (mimeographed) (report on a conference held at the Faculty of Agriculture, University of Ghana, Legon, January 7-8, [illegible]).

coordinating unit for consideration and review; approval should carry a guarantee of funding either wholly or partially.

This phase is intended to establish an approach to regional research coordination which still allows participating countries to develop their own research facilities. Phase II is worthy of particular attention because of the great need to develop and exchange techniques of transferring knowledge to the small farmer. A vast accumulation of scientific knowledge in relation to mechanization already exists; much is being applied well in Equatorial Africa by large-scale farmers. Much less is known about techniques to transfer appropriate knowledge on improved small-scale agricultural technology to the small farmer Relevant coordinated regional research may be extremely helpful, but a flexible approach must be maintained to avoid spending funds heavily at the international level, when research at the farm level should have precedence at the current stage of development.

The secretariat would need physical accommodation in a parent institution. This consideration will be included in the preliminary study undertaken by the *working group*.

Phase III: Regional Research and Coordinating Unit

The final phase in developing a complete regional program is recommended as the establishment of two *regional coordinating units* to be staffed and financed in such a way to pursue its own research and to contract with various national centers for additional work Its function will be both to conduct and coordinate regional research

Keeping in mind the shortage of trained agricultural specialists in Africa, these *regional research and coordinating units* need not be newly-created institutions but can be extensions of existing organization. Each *working group* would be charged with selecting the appropriate body for affiliation.

Regional research and coordinating units supported by technical assistance grants from the co-sponsors should have funds at their disposal to contract with existing national research organizations on a matching basis as determined by the contracting parties. These funds should be used to initiate applied, adaptive, research on the most critical and specific problems relating to agricultural power and land use. Regional coordination of such research should avoid costly duplication and should facilitate dissemination of results among countries. At each phase of the program the recommended period of commitment for the co-sponsors has been for a period of five years, with provision for extensions by mutual agreement of participating countries and the co-sponsors. It is recognised that short term commitments are generally undesirable for promoting agricultural research; at the same time, few political administrations are willing or able to make long term commitments of funds.

The period of five years is not, however, excessively short and should give co-sponsors and participants the opportunity to assess results and renew their financial support.

XII. Recommendation to Support the Preparation of Text Books and Other Teaching Manuals Relevant to Agricultural Mechanization

Frequent reference has been made to the paucity of instructional manuals and materials for teaching institutions and their inappropriateness for uneducated or illiterate farmers in Equatorial Africa. A logical starting place in the acceleration of agricultural productivity is to concentrate on making such pertinent information more readily available. Regional text books would be logical because common climates, crops, and soils extend across the political boundaries of most Equatorial African countries.

It is recommended therefore that policy-makers and grant-aiding authorities give strong support to suitable proposals to prepare books, teaching manuals and pamphlets for use in Equatorial Africa. Such proposals should make provisions for a substantial contribution from African authors, for the final materials to be prepared both in appropriate languages and for the inclusion of guides to prepare appropriate media for the teaching of relevant subject matter to illiterate farmers. The fundamental importance of understanding soil and its management has been emphasized in this Study. Preparation of data relevant to agricultural mechanization would begin with a comprehensive presentation of relevant soil knowledge in suitable forms for use in both teaching and research institutions of Equatorial Africa.

GUIDELINES

Introduction

The following observations on the experience of a variety of mechanization programs have been classified as guidelines. They are intended to identify key considerations to be taken into account in devising future mechanization schemes.

1. Limitations on the small farmer are very severe. Even when future improvements to his income can be effectively demonstrated, farmers frequently have neither the financial means nor the technical guidance to adopt improvements. Mechanization programs involving the small farmer must include provisions for credit and extension assistance.

2. Engine-powered mechanization should not be regarded as an end in itself. Individual farm operators will not be interested in tracotrs if there is no demonstration of improved results. Tractor mechanization is not appropriate unless at least one of the following changes can be demonstrated: (a) offers opportunity to reduce costs; (b) offers opportunity for increasing returns; (c) offers opportunities for reducing risks, (d) offers opportunities for increasing incomes by increasing the scale of operation, even at a diminishing marginal rate of increase [78]

3. No proposed mechanization scheme should be implemented before a thorough investigation has been made into: (a) the nature and suitability of the soil to permit successful mechanized tillage; (b) the productive capacity of the area with respect to the various crops to be mechanized, (c) the level of skill and technical ability of the personnel who will operate the program;[79] (d) the needs, interests, capabilities, and attitudes of the local people; (e) the supply to the area of all necessary inputs, (f) the potential market to absorb increases in production; (g) the market infrastructure.

If some or any of these areas of inquiry represent unknowns, it is much more sensible to conduct initial investigations in the form of pilot schemes rather than to risk heavy losses through implementing a scheme on the basis of inadequate knowledge.

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[78] J. L. Joy, (ed.) *Symposium on Mechanization in Uganda* (Kampala: Department of Agriculture, 1960), p. 14.

[79] No scheme should be implemented unless adequate professional staff is available. It is unreasonable to expect professionals to take single-handed charge of programs involving expensive equipment and demanding much personal time and energy Managers need to be in a position to discuss their project problems with other professional men. It should be possible for a manager to leave his operation for some time in competent hands. A manager cannot be expected to function well in a program where his immediate assistant has artisan's training. If the supply of suitable management personnel is inadequate, it is probably inadvisable to launch a new program.

4. Tractor-hire services have been sponsored generally by governments. They serve a useful function in introducing engine-powered technology into areas in which further development is impossible without additional power. However, private individuals usually are able to run contracting operations more efficiently than government departments operating on the basis of subsidies. Specific plans should phase out subsidies since efficient and intensive management with close accounting procedures are essential to successful tractor operations. Charges for work should be related to actual costs of operation. Tractor-hire services subsidized by the government should avoid charges which severly undercut private operations.

5. Training opportunities have an important bearing on the ability of people involved in development programs to appreciate the intentions of its sponsors and understand the ature of the technology involved. The following are appropriate guidelines: (a) before the implementation of a mechanization program technology, adequate training facilities in the proposed area should be provided. Instruction with oxen power and tractor power should be demonstrated on specific crops and soil types of the area, (b) non-degree awarding agricultural institutions currently train professional agriculturalists who tend to move away from practical agriculture. There should be a genuine effort to inculcate through the curriculum an appreciation for the place of the practical farmer and farm worker, (c) degree-awarding agricultural faculties of the univ ities train professionals who generally occupy positions superior to diploma-holding professionals. These professionals are intended to deal with the problems of agriculture, the curricula at both levels should engender respect for the practical farmer, (d) careful distinction should be made between types of employment for which the degrees and the diplomas train students. Both occupations are important in the economy of the nation, it is inappropriate to regard the diploma student as a second-class professional

6. Programs of agricultural mechanization must fit the economic context Specific mechanization projects must be analyzed to determine necessary economic changes for successful mechanization with respect to the following aspects of the economic context:

a. Farm structure. The average size of farms and the distribution of holdings should be appropriate for the proposed scheme, or the possiblity of changing the structu e should be examined.

b. Increase in the volume of farm production. The market system must be capable of handling substantial increases in the volume of production. This necessitates analyses of: (1) the road and transport infrastructure to determine its capacity; (2) the market channels; (3) demand for the product to determine whether the expansion of the areas product will influence

local market prices, regional market prices, national market prices, and international prices;[80] (4) the volume of inputs required in the area.

c. The entrepreneurial capacity of the local farmers. The level of achievement in the management function is an important determinant in deciding what level of extension service is necessary, and whether private enterpreneurial activities should be encouraged. It involves the consideration of: (1) education of participating farmers, (2) local systems of farming practice; (3) comprehension of the money economy

d At the macro-level of the economy, the scheme must not be considered in isolation from other agricultural schemes in the country or in the larger geographical region Analytical considerations should be given to the aggregate effect on both the product and factor markets (1) there will be an aggregate effect on the market prices for both inputs and outputs, (2) the aggregate effect on international prices can be estimated, (3) the aggregate effect on international prices for imported inputs may lead to an increase in demand for foreign exchange which must be met by the national economy, (4) labor substitution mechanization schemes must be recognized as displacing employed labor in an economy which may have difficulty in absorbing it elsewhere, (5) the non-farm sector of the economy can only be expanded slowly in developing countries, even if it expands to serve the agricultural sector, thus too rapid agricultural mechanization can lead to substantial unemployment or underemployment of the rural population

7. There is need for machinery testing facilities, especially comparative tests of implements designed for use in Equatorial Africa. In some cases agricultural machinery manufacturers might cooperate as they are well-equipped for testing. Many have vested interests that make more impartial institutions better suited to organize these tests but universities or colleges should not become involved in adjudicating the relative merits of different commercial machines. Testing is especially important when agricultural machinery is duty-free. Some form of impartially operated testing is necessary in order to issue import licenses Machinery manufacturers should be willing to support or conduct tests according to national specifications

8 Vigorous attempts should be made to standarize equipment in any one agricultural area This would encourage the establishment of satisfactory repair, maintenance, and training services.

I. Strengthening National Research and Development Institutions

Independent nations take natural pride in the achievement of their own institutions and the existence of well-established national research

80 If the product is intended to move into the international market, its quality must compete with established world supplies.

institutions is a prerequisite to the successful promotion of coordinated regional research. No nation is willing to participate in regional (*i.e.*, international) programs of research until its national research has established a substantial body of knowledge related to its own agriculture. Thus, to work through and strengthen the national research institution is a most important step in developing a framework for regional cooperation. Moreover, as a preliminary stage, this is a positive step which can be taken while a number of alternative approaches to developing a regional research program are under investigation.

Relevant problem areas are: selection, application, use and maintenance of equipment; training of managers, supervisors and operators; determination of development priorities for both projects and localities, determination of priorities in research, transferring knowledge and techniques to poorly educated or reticent farmers. There is enough accumulated scientific expertise and knowledge to guide the agricultural development in Equatorial African countries Agricultural productivity can be increased by making man a more efficient user and director of power However, greater capacity of mechanized operations means that mistakes are magnified and poor judgments become costly Therefore, high priority must be given to the development of local research conducted by national agricultural institutions

II <u>Selective Mechanization of Small Farms</u>

Mechanized technology can be introduced into areas of small farms having high agricultural potential. Mechanization can facilitate the cultivation of more land; the improvement in yields through more timely cultivations, double and triple cropping, and the improvement of transport facilities Appropriate mechanization is favored by. (1) local demonstrations of recommended techniques, improved tools, and the use of modern inputs; (2) machinery hire services, operated by the government if no private entrepreneurs are available, offering services at realistic prices for a limited time period (to be withdrawn as private operators become established); (3) the presence of adequately equipped service workshops and spare-parts stores; (4) availability, for short-term contract work, of heavy crawler equipment for preparation of new land, (5) training schools similar to Narosurra, Kenya, for small farmers and private contractors to learn the skills of mechanized farming, (6) appropriate credit facilities; (7) introduction of high-value crops with an adequate market, (8) good market infrastructure.

Realistic conditions for mechanization should be established in order to select most suitable areas for accelerated development. Areas should be eliminated if mechanization will not lead to a net increase in agricultural production or will lead to a substantial increase in local unemployment, increase disguised unemployment or increase underemployment.

III. Improvement of Small Tools and Implements

The following are vital considerations in developing new tools and implements and improving those already in use: (1) adapt tools for more efficient performance and speedy work; (2) minimise fatigue by improved balance and working position; (3) reduce injury or wear to man or animal; (4) keep weight low for easy transport; (5) construct from local readily-available materials; (6) choose the most simple design appropriate to the job; (7) design for specific tasks, and with only simple adjustments; (8) require the least maintenance and preparation for use; (9) construct so that parts can fit together only one way; (10) secure firm fastening between handle and blade; (11) eliminate wherever possible, the need for wrenches (spanners) or special tools for adjustment; (12) make simple tool clamps with no nuts or pieces to lose; (13) use self-locking pins chained to frame for joining parts; (14) design to accommodate high work-loads caused by unusually dry or hard conditions (animal toolbars should be capable of pulls up to 454 kg.); (15) give careful attention to improving drawbar hitches.

IV. Establishment of Farmers' Animal-power Training Facilities

Facilities for training farmers in the use of animal-powered equipment can be established at special centers or as subsections of agricultural institutions. Training institutions should be simply organized and appropriate to the local rural situation. The major considerations are enumerated below.

1. Appropriate Facilities (a) about ten hectares of farm area, (b) simple improvements to traditional buildings, (c) suitable accommodations for two instructors with every ten to fifteen young farmers, (d) simple compound and sheds for animals and stores, (e) open-sided shed with good shade from the sun for instruction and practical work;

2. Trainees (a) courses to commence just before the beginning of the cropping season and last the full season, (b) farmers' sons and boys sponsored by local farmers selected as trainees to be at least 16 years old, (c) trainees to bring with them a pair of full-grown bulls or oxen. Loans for purchase available in exceptional cases as in Niger where animals are actually selected by the center, (d) animals to be given a thorough veterinary inspection and vaccination;

3. Training Program (a) instruction and supervision on animal use and care, (b) trainees to be able to train animals themselves by the completion of course, (c) progressive training of animals from hauling logs to plows, carts and to other implements, (d) instruction in manufacture of yokes, (e) instruction in implement improvement, (f) instruction in animal-powered plowing and cultivation and cropping practices;

4. Practical Farm Training (a) having learned plowing skills, trainees return to sponsors' farms to plow land but remain under supervision of training instructors, (b) encourage trainees to undertake contract plowing, (c) charges to be fixed for all work done under supervision, (d) money collected for work shared (equally, or on pre-established point system based on merit) at the end of season to provide capital for trainees to commence their own work in the following season;

5. Training Continuation (a) following training with the plow, instruct in next farming operation, (b) also instruct in the use of modern multi-purpose animal toolbars and other appropriate implements, (c) trainees introduced to new crops, improved cultivation techniques, use of pesticides, seed dressings, fertilisers, pasture control, animal feeding, and other techniques appropriate to the locality, (d) instruction in simple implement maintenance and farm carpentry, (e) trainees return to own or sponsors' farms for practice at each stage of the cropping season;

6. Financial Arrangements (a) some form of financial assistance may be necessary for trainees to purchase their own tools, implements and other inputs, (b) training center may provide these inputs on a loan basis, using trainee income from contract work to defray expenses, (c) provision of free board and lodging with small amount of pocket money, (d) some return from trainees income may be expected after his return to farm work, (e) training center to grow most of required food, (f) instructors to have adequate transport and expenses covered for post-training visits to trainees when working on farms in the locality;

7. Follow-up Program: A strong follow-up program of all trainees is important. A year or so after their training period it should be possible for the students to return to the training center for refresher courses, additional training, and an opportunity to clear up any problems encountered in the field. Successive refresher courses can help to maintain enthusiasm for the techniques which have been learned.

V. Establishment of General Training Facilities

The availability of capable instructors sympathetic to farmers' problems is vital to developing a mechanised agricultural technology. In the contemporary situation, few farmers would be able to enter agricultural training institutions; most teaching would be undertaken in the field by extension workers who must be adequately schooled in the relevant practical skills of agriculture.

In order to strengthen training facilities in agriculture, the following are guidelines for policy-makers:

1. Present extension workers should have ample opportunities, through

regular refresher courses, for practical training on the selection, application, use and maintenance of improved implements and farm power units. Foreign-based local farm machinery agencies can provide information and training facilities;

2. Agricultural extension services should be expanded by choosing personnel well qualified in agricultural mechanization, and services should be concentrated in areas of greatest agricultural potential;

3. Time allotted to practical training and selection of improved implements and machinery should be expanded;

4. Curricular content of all training institutions should be carefully reviewed regularly to eliminate unnecessary or irrelevant theoretical courses, and to keep skills related to practical problems of farmers;

5. Training for farm-equipment advisors and technicians should emphasize the interrelationship between improved equipment and improved cultivation practices;

6. Training schools for agricultural mechanization should be considered as appropriate adjuncts to agricultural colleges and/or research institutions;

7. More manuals and instructional literature for the training of extension agents written in appropriate languages are needed, and special techniques for instructing illiterate farmers;[81]

8. A comprehensive training program on the use, operation and maintenance of farm machinery can be a required part of any agreement for purchasing farm machinery under loan or on credit. The cost of this training should be included in the terms of the loan, and training should be completed satisfactorily before the equipment is delivered. Farm machinery dealers should be encouraged, or even required to offer training courses;

9. Loan applicants should be tested for mechanical aptitudes and responsible attitudes. Any training given to loan applicants should (a) be specifically related to the equipment being purchased and demonstrations take place in the location of intended use, (b) include after-training through visitation of the user on his farm by extension agents or the agents of the equipment dealers, (c) insure that extension agents are familiar with the content of any courses taken by farmers in their own location;

10. Where foreign specialists or advisors are employed, the host country

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[81] It is possible to use agricultural literature, machinery manuals and other literature in local schools where the children of many illiterate or semi-literate farmers are students. Students may then help their parents to understand what is written in their own language. However, a sociological problem involved in this observation: few parents take kindly to receiving instruction from their children. Social psychologists can assist in this kind of approach to technical education.

should supply at least two nationals to be trained similarly to take over major responsibility for the program at the earliest possible date.

VI. Provision of Funds and Equipment to Training Institutions

Obtaining loans and gifts of equipment and funds for training institutions from major companies of a country requires considerable diplomacy between the appropriate government agencies, college administrations and the companies. Clearly, a considerable fund of good-will can be established in this way between the training institutions and the companies, and between potential customers (current students) and the companies.

The following guidelines are presented:

1. Principal manufacturers and dealers can be requested to give special discount privileges to training facilities;
2. Training facilities then should be willing to meet the costs of repair;
3. Local dealers can provide instruction and demonstration in correct use of equipment;
4. Literature of all types, in appropriate languages and media should be available from equipment dealers;
5. Equipment on loan should never be used for commercial purposes;
6. Several brands of equipment should be demonstrated in the training institution, although governments should limit the number of types in practical operation in any one location;
7. Consignments of equipment and replacement parts should be renewable on an annual basis by mutual agreement between dealers and teaching institutions;
8. Major machinery importers should be enlisted to support adequate training programs in addition to dealers;
9. Machinery companies who benefit from having trained personnel from these institutions in their employment should provide funds and equipment to the training facilities.

VII. Development of Adequate Repair and Maintenance Services

The following considerations are considered important in the provisions of adequate repair and maintenance services for agricultural equipment:

1. Any government purchases of agricultural equipment should include all recommended spare parts and basic maintenance tools equal to at least 20 percent of the value for the total order, based initially on two years' requirements;
2. Machinery manufacturers, importers or dealers must cooperate in

setting up suitable sales and service facilities;

3. Governments should be willing to permit duty-free importation of agricultural machinery or at least for spare parts and maintenance equipment;

4. Governments are urged to permit the re-exportation, and exchange of unneeded spare parts, for farm machinery which are unusable or surplus to the needs of the country without penalty, export tax, transfer tax or license. Such concessions would encourage distributors to stock more parts, with opportunity to recover without penalties part of their costs due to changes in market demand, early obsolescence, improvement in repair experience, and mistakes in ordering;

5. Governments should regulate the number of types of equipment imported into a country, avoid confusion over spares, repairs and maintenance services;

6. Governments should be encouraged to establish appropriate technical and vocational schools in the mechanical arts and trades. Special assistance should be given to village blacksmiths and artisans in rural areas by providing short courses in metal work and financial aid in the purchase of improved tools.

VIII. Establishment of Service Branches

The mechanisation service branch is conceived as part of the field operations of the national agricultural institutions. The organisation of service branches is envisioned as a later development in the mechanisation process. Branches may serve as operational bases for extension agents in agricultural mechanisation. The numbers and suitable location of service branches must be determined separately for each individual country.

The following are considered appropriate areas of operation:

1. Testing and evaluating field equipment from which recommendations can be made to farmers;

2. Specific assistance to farmers in improving skills with animal-powered equipment in order to assist in (a) the decision to buy oxen, (b) the selection of oxen, (c) the purchase of oxen, through credit facilities, (d) the training of farmers and oxen, (e) the training of oxen for subsequent sale to farmers, (f) the decision of individual farmers whether to move from animal- to engine-powered technology;

3. General advice and demonstrations in the use of modern inputs as these pertain to mechanised technology at all levels of power, and to conduct local experiments with new forms of agricultural technology.

Supervision of tractor-hire services should be a separate and extremely important function of mechanisation service branches. This function should be managed by special field supervisors coordinating the practical operation of government-owned tractors and equipment. The field tractor-hire supervisor

should have had substantial driving experience, should be responsible for 5 to 10 tractor operators, and receive 10 to 20 percent more in salary than the drivers.

The observations enumerated below are considered germane to the area of tractor-hire operations:

1. Function of field supervisors should include (a) coordination of field work and appointment of drivers to each job, (b) control the maintenance of tractors and implements under his supervision, (c) check on field adjustments of implements and give instruction in this skill to drivers, (d) supervise drivers' duties to keep tractor logs and job records, and make routine checks on the tractors and implements, (e) supervise fuel supplies to the drivers, (f) maintain honest practices, (g) preplan field operations with the general supervisor;

2. Field conditions (a) smallest size field to be worked at the standard rate should be 2 hectares, fields smaller should be surcharged 50 percent, very small and irregular fields should not be worked, (b) tractors should not be sent to an area having less than 10 hectares, (c) farmers must guarantee land suitable for tractor operation, and field supervisors should make inspection for obstacles following farmers' guarantees;

3. Payment (a) contracts must be made in advance with farmers, (b) payment, or a substantial part, should be in advance, (c) payment may be arranged as a debit to cooperative accounts, (d) farmers should sign or otherwise record satisfactory completion of work, (e) charges should be on an hourly, rather than an area, basis, (f) charges should be based on economically sound costing procedures, and not so heavily subsidized that private operations are impossible in the same area;

4. Training (a) operators should not only be licensed drivers but also skilled field operators, (b) mechanics should qualify at appropriate technical schools and be able to drive on the road, (c) machinery suppliers should be willing to assist in training and selection of operators, (d) all training should be on a continuing basis;

5. Maintenance support (a) machinery suppliers should be willing to provide local repair and maintenance facilities; (b) suppliers should stock a complete range of parts for supply on demand of at least 85 percent, (c) regular replacement needs should be stocked in field workshops, (d) mobile service trucks should provide emergency field repairs.

IX. Mechanization of Private Farms and Private Ownership of Agricultural Machinery

The reservoir of human skill and initiative in the private sector of an economy has been referred to in the United States President's Advisory Committee Report on the World Food Problem. Private farm mechanization can be

facilitated with supervised credit facilities for *bona fide* farmers to purchase equipment. Such farmers should be expected to undergo minimum training. Equipment should be approved by an appropriate committee of the Ministry of Agriculture; sales agencies should be approved and have adequate provisions for repair services and stocks of spares.

When a number of private farms in a given locality acquire approved mechanized equipment, the appropriate ministry should appoint a mechanization advisor, one advisor per 25 tractors or tractor-loans in the area should be adequate. When a private farmer or contractor becomes self-sufficient, the advisor should shift his attention to new loan recipients.

The mechanization extension advisor should visit tractor owners at least once a month. His duties should include:

1. Providing necessary instruction, checking maintenance, and assisting with simple repairs;

2. Assisting with unusual problems;

3. Reporting to the loan agency on the farmers' progress with the equipment, although he should not be responsible for collecting payments. This is the machinery supplier's responsibility, advice and the collection of dues should be separate.

Private ownership of machinery can be encouraged by basing purchase arrangements on potential incomes of intending purchasers. Interest of private entrepreneurs in contract work can be stimulated by an association of machinery manufacturers to assist in the purchase of tractors and other agricultural implements. Similar assistance also can be extended to competent hand- and animal-powered farmers to replace or supplement their present power with small engine-powered tillers or tractors and implements.

X. Commercial Enterprises as Economic Catalysts

The differentiated approach to economic development has been described by de Wilde[82] as one which is capable of involving the local farming community in several levels of development simultaneously. With such an approach several programs of mechanization can be linked together in an overall plan of development. Such an approach can simultaneously incorporate private enterprise in large and small-scale mechanization programs, private or government-sponsored tractor-hire services and an appropriate scheme of improvement for the small farmers in the area. When one or more large-scale commercial enterprise becomes involved, careful planning can enable the developing infrastructure to benefit the small-scale farmers as well.

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[82] De Wilde, *et. al.*, *Experiences with Agricultural Development in Tropical Africa*, Vol. II, p. 441.

With such an approach, it is important to include large-scale operators in planning from the outset. The management of a commercial concern consists of well-qualified professionals whose experience can be most useful. Further, profit-motivation is essential in commercial enterprises, and such cooperation can have a stimulating effect on the way public enterprises are operated. Public enterprises need not be wholly dependent on subsidies.

XI. Coordination of Regional Research

The recommendation to coordinate research and development of agricultural power and land use on the basis of regional cooperation between national agricultural institutions has been presented in two parts: (1) the temporary establishment of a *working group*, within the framework of a *council of policy-makers*, to work out operational details for region programs and (2) the establishment of two *regional coordinating units*, one for eastern and the other for western Africa, to follow after the function of the *working groups* is complete. The *regional coordinating units* are not recommended as permanent establishments, but rather of fairly short-term duration, say five years with renewable options, so that participant nations are not required initially to make long-term commitments to a program until sufficient time has passed to test its acceptability. This recommendation on time is recognized as a compromise between the unsuitability of short-term commitments in economic development, especially that involving agriculture, and the unwillingness of governments to accept long-term financial commitments in supporting new programs.

The objectives of developing regional research are to coordinate work designed for selective mechanization, to help provide necessary financial support and to circulate information from research and development investigations. Where agricultural conditions are similar in different areas within the region, duplication of this kind of work has been costly. *Regional coordinating units* should receive financial support from both co-sponsors and participant countries. Co-sponsors would be members of the United Nations outside the region, private foundations, inter-governmental organizations such as FAO, UNDP, IBRD; and participant countries would be cooperating countries within the region, relevant international and inter-regional research organizations such as EAAFRO, the IITA, the proposed West African Rice Development Association and the enlarged East African Natural Resources Research Council, and inter-regional African organizations such as OAU and ECA.

It is probable that a *regional coordinating unit* would be attached to an appropriate research organization within its region. The *working group* would have responsibility to determine the most appropriate locations for the *regional coordinating unit*. The locations to be considered may be any of the national agricultural institutions of participant countries or international agricultural institutions. There are a sufficient number of agricultural

institutions already established in eastern and western Africa to insure the existence of adequate facilities. Possible locations for investigation are:

1. Eastern Africa

(a) Nakuru, Kenya, (b) Addis Ababa, Ethiopia (the operational location at Holetta), (c) Morogoro, Tanzania

2. Western Africa

(a) Accra-Ho-Keta Plains, Ghana, (b) Tamale, Ghana, (c) Bouaké, Ivory Coast, (d) Ibadan, Nigeria, (e) Kaduna/Zaria, Nigeria (f) Bambey, Senegal. Factors for and against national institutions, and international foundations such as the EAAFRO and the IITA must be considered by each *working group*.

Another area of inquiry for each *working group* should be the composition of the *regional coordinating units* in eastern and western Africa. Day-to-day regional affairs would come within the domain of a full- or part-time secretary and staff, but a Board of Directors consisting of representatives from participant countries and the co-sponsors could be appointed to direct the general policy of the *regional coordinating units*. Such a Board may evolve naturally from the functions of the original *council of policy-makers*.

In exploring the possibilities of encouraging and coordinating regional facilities for research and development in agricultural power and land use, the following points are likely to favor their acceptance and continuance:

1. Established institutions should be strengthened and incorporated into the research programs and;

2. Universities should be regarded as particularly appropriate institutions for research work, in cooperation with national research institutions, because of their relatively stable existence, longevity, and contact with students going into agricultural professions;

3. Wherever prestige is involved, it should be accorded to national institutions in preference to international institutions;

4. Distribution of research should attempt to give equality in prestige to participating nations;

5. African policy-makers should be involved and committed to functional plans to coordinate regional research;

6. Short-term commitments are likely to be more attractive to potential participants, at least in the initiation phases;

7. Any inclination to create regional centers should be avoided unless specifically charged to do so by co-sponsors and participants operating through the *council of policy-makers*;

8. Mechanization research and development sections may prove most effective when grafted onto functioning national research centers. This is particularly applicable where national or international commodity research centers already have been established. Indeed, the promotion of commodity-oriented

research may be more meaningful in generating information on applied mechanization than promoting research purely in mechanization without being linked into a specific product;

9 Coordinating research on a regional basis can draw together extremely useful information from commodity research institutions and elsewhere for machinery manufacturers who are not themselves in a position to gather this information;

10. Coordinating regional research should merit the active support of Equatorial African national governments, governments of nations involved in bilateral and multi-lateral technical assistance programs in Equatorial Africa, and machinery manufacturers with market interests in Equatorial Africa.

XII. Preparation of Textbooks and Teaching Manuals

The objective in supporting programs to prepare textbooks, teaching manuals, and instructional pamphlets is to provide sound bases of factual information for agricultural education at all levels, and for research. Such programs should include:

1. Textbooks should be prepared from African sources of data and involve significant African authorship;

2. The proposal should contain sufficient prestige and other incentives to attract capable writers;

3. The proposal should contain provisions to assist African writers wherever skills are inadequate;

4. The proposal should contain methods and media to make relevant material available to farmers, while the more technical information would be for students, teachers, and extension workers at all levels.

The implementation of a program to prepare such literature would be enhanced by: (a) African sponsorship, (b) appropriate advisory committees selected from the geographical regions of Africa, (c) major authorship accredited to Africans, (d) substantial share of royalties paid to the African authors, (e) foreign advisors or authors being limited, when possible, to the authorship of the first edition, (f) books published in Africa, (g) books published first in English or French and, subsequently, in the major languages of the region, (h) facilities provided for the working authors to meet in conference at least annually, (i) drawings and pictorial illustrations provided as needed.

AGRICULTURAL MECHANIZATION IN EQUATORIAL AFRICA

PART TWO

A DOCUMENTARY FIELD STUDY

PART TWO

PREFACE

When man began using stone tools, he became an innovator and using his ingenuity to make his work easier. Mechanization, when defined broadly as in this Study, includes the use of hand tools, animal implements and engine power. There is no question that mechanization will be employed; the question is at what level and to what degree. These questions do not seem difficult to answer until one considers that agriculture is only one aspect to be considered and that mechanization is but a small segment of agriculture. In other words, questions about mechanized agriculture must be considered in relation to much broader social, economic, and political issues. Thus, the interrelations become very complex. Undoubtedly there is no single or simple path to development. The role of mechanization in agricultural development will continue to be a matter of opinion and conjecture.

Part Two of this report presents the data collected by the Study team. It is an attempt to describe the present agricultural systems in Equatorial Africa and to view mechanization in proper perspective. Much sifting of information was necessary to attempt to separate the relevant from the irrelevant and facts from opinions. In Chapter II the various levels of mechanization (hand, animal, engine) are considered and in Chapter III the various operations (tillage, planting, weeding, harvesting, processing) are discussed. Liberal use of photographs with extensive descriptive captions are included to help describe the present systems.

Chapter IV contains the analyses of present systems and leads to Chapter V which suggests improved technology for the future and leads to the Recommendations and Guidelines presented in Part One.

It is the hope of the authors that this compilation of information and analyses will lead to more effective utilization of mechanization in agriculture.

CHAPTER I

INTRODUCTION

The Nature of a Mechanization Study

The peoples of the African nations are anxious to develop their economies so that the majorities of their populations are released from the strictures of subsistence livelihoods. History of the more advanced nations of the world gives adequate evidence that such aspirations are not beyond the realms of practical and economic realization. Moreover, growing interest in international cooperation has led to the availability of many facilities for the sharing of applied and adaptive research to assist in the development of African economies.

African economies are primarily agricultural. The key to economic development for these nations lies now in raising the productivity of the agricultural population. However, such expansion cannot be achieved in Africa without a concomitant expansion in effective demand for agricultural produce.

Agriculture is defined by the United States President's Science Advisory Committee as "the utilization of biological processes, on farms, to produce food and other products useful to man".[1] In the same report the Committee emphasizes the dual role of economic development in the world's agricultural nations: raising agricultural productivity (production) and increasing general prosperity (effective demand), in order to alleviate the critical shortages of the "World Food Problem".[2]

Agricultural production can be raised either by bringing more land under cultivation or by increasing the productivity of land already under cultivation. Therefore, understanding the complex technical and economic interrelationships of agricultural productive processes and the way these processes can be modified to raise the agricultural production of the African nations is vital to a mechanization study. The emphasis of this Study lies within the technical and economic limits of the productive processes.

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[1]President's Science Advisory Committee, *The World Food Problem* (Washington, D.C. : U.S. Government Printing Office, May, 1967), Vol. I, p. 60.

[2]"The cornerstone of economic progress of any nation is the development of its natural resources and manpower. Many of the developing nations must concentrate on agricultural resources as the foundation for building self-sustaining, productive national economies. Conversely, the growth of the entire national economy will be essential in the future to increase agricultural production, which will depend critically on the farmer's ability to purchase fertilizers, tools, high-yielding seeds, pest controls, and irrigation water. To be able to purchase the required materials, farmers will need to sell a major proportion of their harvests, which means that there must be increasingly prosperous customers who can buy farm products."
Ibid., p. 13.

The significance of effective demand must not be neglected. Changing certain technical inputs in the productive processes is only part of the overall economic picture, and considering only the mechanization of the productive processes without also giving consideration to the problem of increasing demand for the resultant increase in production becomes a self-defeating exercise. In the process of national development, commercialization of the agricultural sector and widening the distribution of income among potential consumers must be concomitant factors to mechanization since raising productivity leads to the production of surplus beyond the immediate demands of the farmer and his family. Thus, it is reasonable to assert that mechanization of the productive processes will involve the farmer in higher costs which have to be met out of resulting increases in income if there is an adequate effective demand. Such demand may be stimulated by appropriate economic policies. If this consideration is neglected, a proposed program of mechanization may very quickly run into problems of surplus production. The outcome will be to declare the scheme a failure when, in fact, the scheme itself may have been technically far from being a failure, only the planning horizon had been too limited in perception of the problem.

Commercialization involves the farmer in producing for a market in which effective demand also guides the producer's activities: this is an additional factor to the skills, abilities, and availability of resources used by the farmer in his productive processes. The market structure must be adequate primarily to facilitate the flow of produce from producer to consumer and, as commercialization becomes more sophisticated, to relay changes in effective demand to the producer in such a way that he can make adjustments to his productive processes.

Within this framework mechanization assumes a broad perspective. Mechanized technology can be applied to production, movement of produce through market channels and to its being processed into convenient forms for consumers. However, in the earlier stages of a nation's development, mechanized technology in the productive processes generally takes precedence; farmers and agricultural scientists concentrate on experimenting with any new facilities of mechanized farm power; and the market is generally not sufficiently developed to provide reliable incentives for commercial production.

The large majority of African small farmers generate their own farm power. Estimates from a sample survey taken in Ghana in 1963 show that 99.51 percent of agricultural power was hand power; the balance consisted of 0.14 percent animal power and 0.35 percent engine power.[3]

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[3]Walter Birmingham, I. Neustadt, and E.N. Omaboe, *A Study of Contemporary Ghana*, Vol. I:*The Economy of Ghana* (London: George Allen and Unwin, Ltd., 1966), p. 222.

Utilization of machinery can increase the output of a single man by many times. The output of a man is rated at ¼ horsepower, therefore when this man is efficiently operating a Massey-Ferguson 165 tractor with approximately 45 drawbar horsepower, with properly matched equipment, he can theoretically do the work of 180 men.[4]

Generally it appears that the productivity of labor and land can be increased by the assistance of mechanized power. Assuming the production function of the traditional economy cannot be reorganized easily to be more economically efficient and that availability of hand labor remains fixed, mechanical assistance becomes essential to increasing the input of power into African agriculture. Moreover, there is no immediate land scarcity in Africa, but *the increasing costs of clearing additional land require that much of the effort to increase agricultural production should be concentrated on land already under cultivation.*[5] Contemporary judgment in the present decade suggests that, in fact, agricultural expansion during the last decade has been obtained generally by expanding the area of land under cultivation.[6] Whether agricultural production in Africa is to be increased by bringing new areas under cultivation or by the intensification of cultivation on land in current production, it is general opinion with some supporting evidence that there is a dearth of farm power in Africa.[7]

In the developing free world, more machinery is badly needed -- not as a labor saving device, but to increase productivity. At the present time, machine power available to the farmers of Asia, Africa and Latin America averages only a fraction of the more than one horsepower per hectare utilized by the farmers of Europe and the United States. This lack of power makes it difficult to prepare seed beds efficiently and timely and to place seed and fertilizer accurately, both of which can contribute markedly to improve yields and the economical utilization of these inputs. Although there are one or two exceptions, an analysis of yields in various countries indicates that a power level approaching 0.5 horsepower per hectare is needed for an efficient agriculture.[8]

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[4]T.J. Shambaugh, Jr., *Summary of the Developments in Progressive Mechanization for the Hand Farmers and Mixed Farmers in the Savannah of Northern Nigeria* (mimeographed) USAID Project No. 620-11-190-771, Special Report No. 68-4 (Maiduguri, Nigeria: The Industrial Development Centre, February, 1968), p. 1.

[5]President's Science Advisory Committee, *The World Food Problem*, Vol. I, p. 19.

[6]*Ibid*, Vol. II, p. 378.

[7]It has been estimated that it will be necessary to increase African tractor utilization by .44 hp./ha. to meet the minimum requirement of 0.5 hp./ha. by 1998.

G.W. Giles, "Agricultural Power and Equipment," President's Science Advisory Committee, *The World Food Problem*, Vol. II, p. 192.

[8]President's Science Advisory Committee, *The World Food Problem*, Vol. I, p. 87.

The Study was confined to Equatorial Africa and, while some generalizatio[ns] are possible, most information obtained from one country should be used only as descriptive of conditions in that particular country. Where geographical, agronomic and climatic conditions are similar, a transference of agricultural experience is feasible; but recognition must be given to the fact that differe[nt] sociological and political situations impinge on technological situations. Thus, *generalizations are presented only circumspectly, recognizing the essential need for adaptive research*

> . . . to gain an understanding of the principles governing plant and animal production under the conditions, soils, and climates existing in developing countries. . . The products of technology and "know-how" cannot be transferred directly to the developing nations.[9]

The purpose of mechanization in Equatorial African agriculture is the raising of productivity. Since agricultural power used in Africa is overwhelmingly that of human muscle and to a lesser extent, animal power, the definition of mechanization, for the purposes of the Study, includes any form of mechanical assistance used by the farmer, whether in the forms of hand-powered, animal-powered, or engine-powered technology.

The Fundamental Importance of Soil and Crop Management

While mechanization is admittedly an essential factor for increasing agricultural productivity, its success is dependent on good management in relation to suitable soils and crops. Any increased benefits, usually in the form of cash sales, from the increase in crop production due to a new source of farm power must pay for the new farm power. Increases in crop production can result from higher yields and/or greater areas under cultivation.

A soil and land use inventory followed by scientific soil suitability studies for the major crops becomes essential for cultivation management studies, including improved mechanization systems. In Africa, the introduction of scientific soil and crop management work began late. One of the first scientific field studies of soils and vegetation in Africa was made by Shantz and Marbut.[10] Before this time, many field experiments were conducted and many laboratory analyses were made, but they were not related to soil classification and mapping; their results could not be extended to geographic areas of application. [Dr.] Marbut concluded that soil and land-use surveys should be the basis of scientific use of the land.

The Imperial (now Commonwealth) Bureau of Soil Science was established in 1927 in the United Kingdom. In 1930 the report of the Bureau stated:

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[9] *Ibid.*, Vol. I, p. 20.

[10] H.L. Shantz and C.F. Marbut, *Vegetation and Soils of Africa* (American Geographical Society, 1923).

"Soil maps will be constructed for all experiment stations and of the districts around them."[11]

The importance of soil surveys and climate as factors in agricultural development is emphasized by the FAO/IBRD:[12]

> What are the types of soils? What soil surveys have been carried out? Give major characteristics and classifications resulting from these surveys. Fertility and suitability for proposed types of farming and for irrigation. Will there be a drainage problem?. . . Give rainfall, temperature, and other climatic data relevant for proposed crop production.

Support for this position comes from other sources:

> The failure of the great East African Groundnut Scheme in 1949-1950, [totaling 1.3 million hectares, mostly in southern Tanzania] . . .must be ascribed in large measure to a lack of accurate knowledge of soils and their behavior under new methods of cultivation. It is an index both of continued ignorance of tropical soils and of the costliness of that continued ignorance.[13]

> It is recommended to the governments [of East Africa] that land-use, farming, and economic surveys be carried out, and after it has been ascertained scientifically and technically that the development programs have a reasonable chance of success, only then should further orders for tractors and equipment be placed.[14]

The Potential Productivity of Tropical Soils

> The potential crop yields in the tropics in general are decidedly higher than those in the temperate zones. Thus, if incentives and other requirements for production are satisfied, the tropical world can greatly outproduce the temperate world.[15]

> It has been claimed that tropical soils are 'worn out' and that the tropics are doomed to a future of low productivity and rural poverty. There is an abundant body of knowledge today,

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[11] Cecil F. Charter, *The Organization of Soil Surveys in British West Africa* (mimeographed), Communication No. B(g)9, Soil Survey Division (The Gold Coast: Department of Agriculture, 1930), p. 1-10.

[12] Food and Agricultural Organization and the International Bank for Reconstruction and Development, Cooperative Program, *Outlines for Projects to be Presented for Financing* (Rome: United Nations Organization, September, 1967), p. 1.

[13] L. Dudley Stamp, *Africa: A Study in Tropical Development* (New York: John Wiley and Sons, 1964), p. 88.

[14] *Minutes of the Meeting of the East African Machinery Specialist Committee* (Serere, Uganda: EAAFRO, Nov. 18-20, 1963), p. 9.

[15] Robert F. Chandler, Jr., *Challenges in Meeting the Agricultural Needs of the Tropical World* (Address presented at the First Annual Conference of the College of Tropical Agriculture, Honolulu, Hawaii, January 5, 1966), p. 3.

however, to show that the old, weathered depleted tropical soils can be rejuvenated by the application of good management principles including fertilizer application.[16]

Bush Fallow

African farmers traditionally have adjusted their cropping systems to obtain essential plant nutrients from soil minerals. The present system of cultivation observed in contemporary Africa is known as bush fallow or shifting cultivation. For a subsistence agriculture with very low inputs and low outputs, no one has yet suggested improvements. However, with soils derived from granite, and at least 102 cm. of annual rainfall, such a system cannot support more than 7 to 10 persons per square kilometer; with soils derived from limestone, twice this density can be supported.[17]

In the countries covered by the Study, the least dense population is in Tanzania with ten persons per square kilometer; the most dense is Nigeria with 44 persons. Since at least 75 percent of the population is engaged in agriculture, the logical assumption is that bush fallow is a luxury which cannot be afforded any longer. *The alternative to bush fallow is scientific management of all factors of production, starting with selection of soils that are most responsive and managing them scientifically with 20th century inputs.*[18]

Scientific soil management in the Tropics, however, depends upon adapting ecologically-oriented field research that was conducted under similar soil and climatic conditions. Scientific field research in the Tropics is rare and difficult, especially that involving a comparison between systems of bush fallow with the traditional hand hoe and systems of continuous tillage with crop rotation, 20th century inputs, and tractor power.

In Ghana, the CSIR has conducted long-term field trials comparing traditional agriculture with modern tractor farming.[19] For traditional farming field trials, the wild bush was cleared from a plot and planted with two crops of maize (corn) a year for three years. The crop seasons and resultant yields

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[16] *Ibid.*, p. 7.

[17] Richard Bradfield, "The Future of Soils and Crop Research in the Tropics", Symposium: Fertilizers and Their Use in the Tropics, *Proceedings, Soil and Crop Science Society of Florida*, Vol. XXIV, 1966, p. 302.

[18] Under most soil conditions prevailing in both the rain-forest and the savannah in Ghana and Nigeria, raising cultivated crops for a period of two years followed by fallow for ten years should permit sufficient soil nutrients to maintain crop production levels to feed up to ten persons per square kilometer.
P.H. Nye, "African Experience in the Use of Fertilizers in the Production of Basic Food Crops", Symposium: Fertilizers and Their Use in the Tropics, *Proceedings, Soil and Crop Science Society of Florida*, Vol. XXVI, 1966, p. 306.

[19] I. Miller, *Report on the Agronomic Work Carried Out at Kwadaso Central Agricultural Station Up to Second Season*, 1960 (mimeographed) (Accra: Ministry of Agriculture, January, 1962), Part II, p. 3.

are shown in Table I.1. The research scientists abandoned the experiment because of low maize yields due to soil exhaustion.

TABLE I.1 GHANA: SINGLE-CROPPING MAIZE FOR THREE CONTINUOUS YEARS IN TRADITIONAL FARMING FIELD TRIALS

Year	Crop Season	Yield of Dry Grain
		kg/ha.
1956	First	181.4
	Second	-
1957	First	107.5
	Second	-
1958	First	-
	Second	-

Traditional agriculture was then redefined to include one year in field crops and five years in wild bush. The crops grown were cassava, yam, plantain, cocoyam, and maize (corn).[20]

In comparison with this, traditional agriculture was tractorized crop-rotation agriculture, consisting of a five-year rotation (1954-1958) repeated for an additional five year period (1959-1963).[21] The cropping sequence is contained in Table I.2.

In summary, "The average cost of tractor work on the three crops: maize, groundnuts, cassava, was about six to seven Ghanaian pounds per acre [$41.51 to $48.43 per ha.]. Hand work, on the other hand, was about twice this figure for maize and groundnut, and three times for cassava".[22]

Following three years, crops of elephant grass and maize were planted in rotation and always there was a depression in yields. In modern farming, one common explanation is that additional nitrogenous fertilizer is needed for maize because of the wide carbon-to-nitrogen ratio of elephant grass residue.

Traditional systems of farming appear similar throughout Equatorial Africa except in the highlands of Ethiopia, Kenya and Tanzania. A sample survey of the typical tropical traditional cropping system in Ghana provides germane information.

According to the 1963 sample survey,[23] the average field in Ghana is cleared and cultivated with hand hoe, axe, and cutlass for two years, then is

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[20] *Ibid.*, p. 8.

[21] *Ibid.*, p. 9-35.

[22] Average annual rainfall at Kumasi, where this experiment was conducted, is 150.5 cm. and the soil was Kumasi well-drained sandy loam derived from the Cape Coast granites.
Ibid., p. 18.

[23] Birmingham, *et al.*, *op.cit.*, pp. 223-5.

TABLE I.2 GHANA: CROPPING SEQUENCES FOR TRACTORIZED CROP ROTATION EXPERIMENTS

Year	Cropping Season	Cropping Sequence
1954	First	Maize (corn)
	Second	Groundnut (peanut)
1955	First	Maize (corn)
	Second	Cassava
1956	First	Cassava
	Second	Cassava
1957	First	Elephant grass
	Second	Elephant grass
1958	First	Elephant grass
	Second	Elephant grass

allowed to lie fallow in wild bush for six years. Variations in this practice exist, depending upon the relative population pressure on the land. In areas of low population pressure, such as in central and northern Ghana, farmers may clear this land and grow field crops for two to three years among large trees and stumps, then allow wild bush to occupy the area for 15 to 20 years before it is again cleared and cropped. By contrast, near Accra where population pressure is heavy, many fields are cultivated almost every year. Likewise, small garden plots around individual homes and near villages may be cropped to vegetables and tree food crops almost continuously. To keep these tropical soils productive under such intensive use, animal manures, forest tree litter, and composts are used. Very seldom are chemical fertilizers used, although a few experiments and demonstrations have proved their efficacy.

The sample survey also indicated that the average Ghanaian farmer generally tended cultivated crops in two separate locations, one near his village and the other in the bush. At each location (farm) he had two fields each 0.61 hectares in area. Each field was cropped for two years on the average and left in bush to rejuvenate the soil for a period of six years. During any one year the average farmer would grow crops on only 0.61 hectares. Details of the sample survey are given in Table I.3.

Soil Management

Soils in Equatorial Africa have been managed as wisely as available research, extension and the eductional level of the farmer permitted. More scientific and economic answers must now be provided to such fundamental questions as:

1. When pressure of population dictates a more intensive use of the soil, what is a satisfactory alternative to the bush fallow (shifting cultivation) system?

TABLE I.3 GHANA: THE COMMON BUSH FALLOW (SHIFTING CULTIVATION) CROPPING SYSTEM OF THE AVERAGE FARMER

	Village Farm (Two fields)		Bush Farm (Two fields)	
Year	0.61 hectares	0.61 hectares	0.61 hectares	0.61 hectares
1	Field crops	Bush fallow	Bush fallow	Bush fallow
2	Field crops	Bush fallow	Bush fallow	Bush fallow
3	Bush fallow	Field crops	Bush fallow	Bush fallow
4	Bush fallow	Field crops	Bush fallow	Bush fallow
5	Bush fallow	Bush fallow	Field crops	Bush fallow
6	Bush fallow	Bush fallow	Field crops	Bush fallow
7	Bush fallow	Bush fallow	Bush fallow	Field crops
8	Bush fallow	Bush fallow	Bush fallow	Field crops

2. How can soil structure be maintained and soil erosion be controlled?

3. Can use of chemical fertilizers maintain or increase crop productivity?

4. Where a layer of laterite[24] exists in the profile, does clear-cutting and continuous tillage increase the hazard of hardening? If so, what are the critical depths of the laterite layer? Is there a cropping system that can be devised to reduce this hazard?

Restrictive Factors of Crops and Cropping Systems

Crops and cropping systems modify potential increments in productivity that can be contributed by more efficient mechanization systems. On annual row crops such as wheat, grain sorghum, pearl millet, and biennial crops such as sugarcane and pineapple, for example, better-tempered iron in a hand hoe or wider and shallower cultivator shovels on an ox-drawn or tractor-drawn implement can result in substantial increases in the area weeded by one farmer and therefore in total production per man. By contrast, with perennial crops such as banana, coffee, tea, cocoa, oil palm, cassava, rubber, and cocoyam, the same mechanical improvements would make virtually no impact on total production because of the small amount of mechanical tillage employable in their cultivation.

Ecological Factors of Climate, Vegetation, and Anthropic Influence[25]

In Equatorial Africa, wind erosion near the Tropic of Cancer (extending across the southern part of the Sahara Desert) and near the Tropic of Capricorn

[24] Laterite is defined and the management of laterite soils in relation to mechanization is discussed in Chapter II, pp. 2-151 - 2-164.

[25] L.P. Smith, *Weather and Food*, Freedom From Hunger Campaign, Basic Study No. 1 (Geneva: World Meteorological Organization, 1962).

(the Kalahari Desert) is very serious, and deteriorates yearly because of overgrazing by cattle, sheep and goats herded by pastoral nomads. Approaching the Equator, rainfall increases and produces progressively, belts of short grasses (plains), tall grasses (prairie), tall grasses and short trees (natural savannah), tall grasses and tall trees (anthropic or derived savannah), and tropical rain-forest as shown in Table I.4.[26]

In western Equatorial Africa, unless the rainfall is very favorably distributed, annual crop production is minimal in areas where the rainfall is less than 76.5 cm., because of high evaporation and transpiration. When the annual rainfall is more than 153 cm., rain-forests usually exist, topography is most often more rolling, the soils are more highly leached, and the most common commercial crops are perennial ones grown in small openings in the forest. These crops are cocoa, rubber, oil palm, coffee, banana, and cocoyam, with very little potential for mechanized production. The greatest potential for greater efficiency of farm power, whether by hand, animal, or machine, is in the 102 to 153 cm. annual rainfall belts where tall grasses and short or tall trees (savannah) exist, land is fairly level, and soils are not highly leached. On such soils the common annual crops of food, feed, fiber and oilseed are grown, including grain sorghum, small millets, maize (corn), cotton, groundnuts (peanuts), and sesame.

Despite limited crop culture, erosion by water becomes serious in areas receiving less than 76.5 cm. of annual rainfall because of grass burning practices and overgrazing by livestock. Moreover, the total annual rainfall increases inversely the hazards of torrential, gully-washing, flash storms. In most areas receiving more than 153 cm. of annual rainfall, very little soil erosion takes place because perennial crops are grown in small partial clearings in the forest. However, where rural population pressure is great and the rain-forest is cleared for large-scale mechanized farming, soil erosion hazards exceed those of any other place in the world.[27] Erosion by water has not been serious in the 102 to 153 cm. annual rainfall belt in Equatorial Africa because of the practice of shifting cultivation which usually exposes bare soil for two out of eight years; wild bush growth protects the soil during the other six years. On the average, between 5 and 10 percent of the land in this savannah

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[26] Although rainfall is high near the Equator over most of Africa, elevation and wind direction are also modifying factors that determine the amount of rainfall. Variations in mean annual rainfall along the Equator in Africa are from 306 mm. (12 inches) at Chisimaio, Somalia; 1734 mm. (68 inches) at Entebbe, Uganda; to 1836 mm. (72 inches) at Kisangani, Congo (Kinshasa); to 2065 mm. (81 inches) at Boende, Congo (Kinshasa); to 4182 mm. (164 inches) at Libreville, the capital of Gabon.

[27] An example of great population pressure in an area of high rainfall and serious erosion is southeastern Nigeria.

TABLE I.4 EQUATORIAL AFRICA: MEAN ANNUAL RAINFALL AND TYPES OF VEGETATION

Mean annual rainfall millimeters	Type of vegetation
below 510	Desert and semi-desert
510 - 565	Short grasses (plains)
565 - 1020	Tall grasses (prairie)
1020 - 1275	Tall grasses and short trees (natural savannah)
1275 - 1530	Tall grasses and tall trees (anthropic or derived savannah)
above 1530	Rain-forest

belt is in cultivated crops each year. The remainder is either untouched or is lying fallow in wild bush (grasses, weeds, and trees) until the soil has rejuvenated sufficiently to support another cultivated crop.

General Background

Mechanization is being introduced into a wide variety of ecologically different situations and includes a broad range of tools and equipment. Hence, it is useful to consider first the numbers of tractors and agricultural machinery in countries of particular interest. All modern agricultural equipment is imported into African countries; data are available but the publications tend to be two or three years in arrears.

Agricultural Tractors

Data on the numbers of tractors from 1961 to 1967 in the nine countries are shown in Table I.5. Kenya has the largest number of agricultural tractors and Tanzania ranks second, considerably lower than Kenya. In Uganda the number of tractors has risen rapidly and in the other six countries the numbers of tractors are considerably smaller, with a marked increase in Ghana after 1963.

The 1952-56 averages provide a means of comparing the relative numbers of tractors in the decade previous to the 1960's. However, a clearer picture of the relative numbers of tractors can be obtained from the indices, illustrated in Figure 1.1, of tractors in each of nine countries from 1961 to 1967 relative to the numbers of tractors in Kenya in 1961. The number of tractors in Kenya is approximately twice the number in Tanzania. There has been a slight decline in annual purchases of tractors in Kenya, whereas the numbers increased in all the other countries, with the possible exception of Gambia and Senegal where the numbers have remained approximately constant. From these data the level of tractorization is low in all countries relative to Kenya. Over the period the relative increases in the numbers of tractors are substantial: by 1964 the number of tractors in Ghana closely approached the numbers in Tanzania; the numbers in the Ivory Coast increased twelve times; the numbers in Ethiopia

TABLE I.5 AGRICULTURAL TRACTORS IN NINE AFRICAN COUNTRIES, 1961 - 1967
(Wheel and Crawler Tractors over 8 Horse Power)

Country	Item	1952-56 average	1961	1962	1963	1964	1965	1966	1967
Ethiopia[a]	Wheel	31	n.a.[b]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Crawler	17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Total	48	273	250	288	420	393	643	1068
Gambia	Wheel	17	33	38	44	47	52	38	n.a.
	Crawler	1	4	5	4	2	2	4	n.a.
	Total	18	37	43	48	49	54	42	n.a.
Ghana	Wheel	93	n.a.	n.a.	n.a.	1866	1798	n.a.	n.a.
	Crawler	8	n.a.	n.a.	n.a.	368	326	n.a.	n.a.
	Total	101	161	n.a.	n.a.	2234	2124	n.a.	n.a.
Ivory Coast	Wheel	n.a.	n.a.	n.a.	380	398	615	730	n.a.
	Crawler	n.a.	n.a.	n.a.	70	62	90	210	n.a.
	Total	n.a.	78	n.a.	450	460	705	940	n.a.
Kenya	Wheel	3934	5356	5424	5167	4976	4886	5345	n.a.
	Crawler	1020	1066	994	994	807	843	800	n.a.
	Total	4955[c]	6422	6418	6161	5783[d]	5729	6145	n.a.
Nigeria[e]	Wheel	n.a.	186	186	n.a.	n.a.	n.a.	n.a.	n.a.
	Crawler	n.a.	49	49	n.a.	n.a.	n.a.	n.a.	n.a.
	Total	n.a.	235	235	n.a.	n.a	n.a.	400[f]	n.a.
Senegal	Wheel	n.a.	n.a.	125	133	152	n.a.	n.a.	n.a.
	Crawler	n.a.	n.a.	45	47	58	n.a.	n.a.	n.a.
	Total	n.a.	203	170	180	210	n.a.	n.a.	n.a.
Tanzania (Tanganyika & Zanzibar)	Wheel	1292	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Crawler	1238	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Total	2530[b]	1538	1833	2357	2601	n.a.	n.a.	n.a.
Uganda	Wheel	269	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Crawler	144	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Total	413	623	640	550	550	1059[g]	1335[g]	1660[g]

(See notes on the next page.)

Source: (Except where otherwise stated) United Nations, *Production Year Book* (Rome: Food and Agricultural Organization, Statistics Division), Vol. XVII (1963), p. 270; Vol. XX (1966), p. 462; Vol. XXI (1967), pp. 465-6.

[a]Institute of Agricultural Research, *A Preliminary Survey of Mechanized Farms in Ethiopia* (Unpublished paper, Addis Ababa, 1969). Data for Eritrea are not included in this report.

[b]Not available during course of the Study.

[c]Two-year average corrected to the sum of two sub-totals.

[d]Kenya data are for large scale mechanized farming. Tractors on settlements, government agencies and small-scale farms are omitted. Their inclusion would raise the total by about 11.3 percent. International Bank for Reconstruction and Development, Permanent Mission in Eastern Africa, *Agricultural Mechanization in East African Countries* (mimeographed), Report No. 3 (Nairobi: Agricultural Development Service, July, 1966), Tables 7A and 7B.

[e]Government-owned tractors only.

[f]Estimate taken from Malcolm J. Purvis, *Investment Opportunities in Mechanized Farming: A Study of the Economics of Tractor Use in Oyo Divisions of the Western State* (mimeographed) (Ibadan: Nigerian Institute of Social and Economic Research, Consortium for the Study of Nigerian Rural Development, June, 1968), p. 2.

[g]Estimated numbers taken from W.T. Brown, P. Evans-Jones and D.J. Innes, "Implements," Chapter 17 in David Stephen (ed.), *Agriculture in Uganda* (Revised edition, 1968).

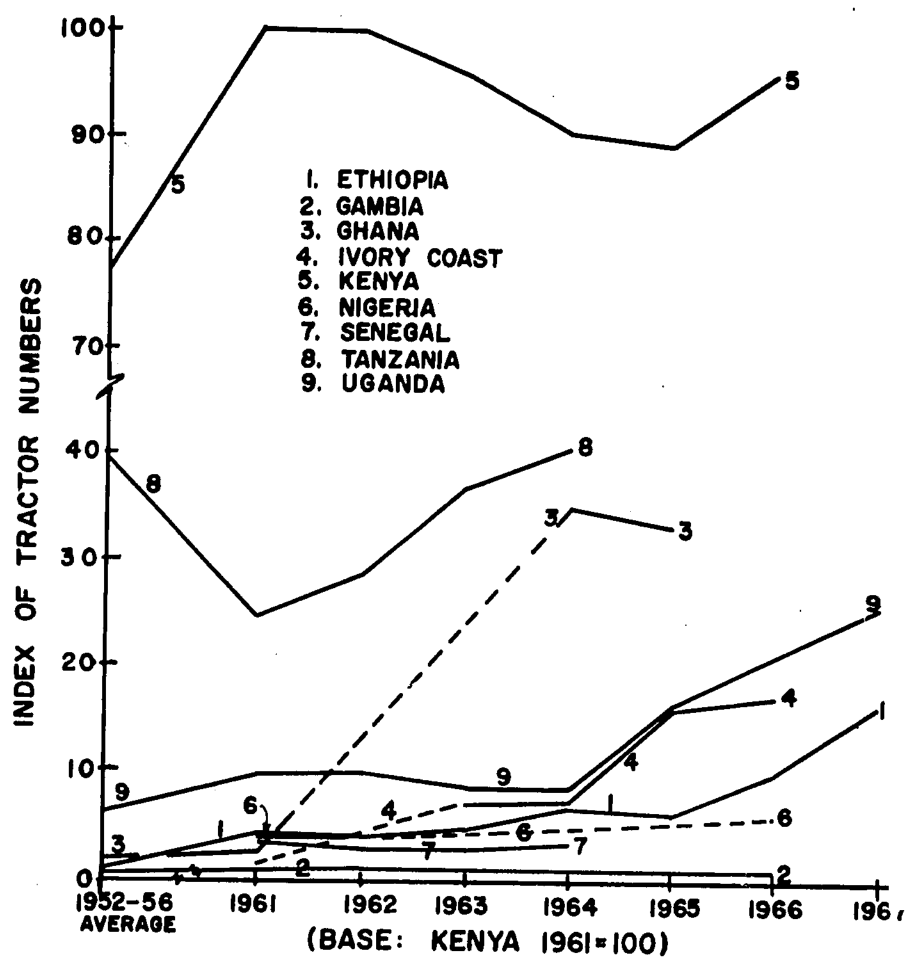

FIGURE 1.1 Indices of Total Tractor Numbers in Nine Equatorial African Countries

increased almost four times; and the Nigerian numbers doubled.

Data presented in Table I.5 consist of both crawler and wheel tractors. Many crawler agricultural tractors are used mainly in the preparation of land for agricultural purposes. Thus, the data for wheel tractors probably are a more accurate measure of the actual level of engine-power employed in agricultural production but the separation of the data into these two categories is incomplete.

Importations: Agricultural Tractors, Agricultural Machinery, Total Imports

The number of tractors operating in a country is a rough measure of the level of agricultural engine-power in use. Perhaps more demonstrative of a country's willingness to invest in mechanized agricultural technology is the relative level of resources currently being spent on tractors and agricultural implements. The number of tractors in a country reflects to some extent the past policies of commercial agricultural enterprises and of governments. The level of importations, especially relative to the level of total importations into the country, is a fairly accurate indicator of current trends in agricultural mechanization with modern engine-powered equipment. Table I.6 shows these basic data for importations from 1960 to 1967.

The indices of importation for agricultural machinery (using Kenya 1961 data as the index base) are illustrated in Figure 1.2. These relative values fluctuate quite widely over the period. Ghana is the largest importer although the trend in the importation of agricultural machinery falls very slightly. Trends in the importation of agricultural machinery rise for Ethiopia, the Ivory Coast, Kenya, Tanzania, and Uganda; countries with falling trends are Nigeria and Senegal; the trend for Gambia is constant at a low level.

These data could be adjusted by a price index for tractors and farm implements.[28] The level of prices in exporting countries rose by the following percentages during the period 1960 to 1965: Canada, 12.4 percent; France, 8.0 percent; Germany, 11.0 percent; USA, 6.2 percent.[29] However, adjustments for changes in price levels are unlikely to change the relative positions of African imports significantly.

Together the data contained in Tables I.5 and I.6 may be used to show proportions spent on tractors and agricultural machinery relative to total imports and illustrate the following trends in the mechanization of agriculture:

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[28]United Nations, *Trade Year Book 1966*, Vol. XX, p. 612.

[29]Data for other tractor and machinery exporting countries are not available from the source cited above.

TABLE I. 6 IMPORTATION OF AGRICULTURAL TRACTORS, ALL AGRICULTURAL MACHINERY, AND TOTAL IMPORTS 1960 - 1967

Country	Item	1960	1961	1962	1963	1964	1965	1966	1967
Ethiopia	Tractors[a] -- quantity	n.a.[b]	n.a.	42	129	128	189	275	n.a.
	-- value[c]	n.a.	n.a.	4.8	9.6	12.4	12.0	n.a.	n.a.
	All machinery -- value	n.a.	n.a.	12.0	24.0	31.5[d]	35.3[d]	43.6[d]	n.a.
	Total value of all imports	n.a.	n.a.	1035	1112	1231	n.a.	n.a.	n.a.
Gambia	Tractors -- quantity	4	11	15	11	24	10	n.a.	n.a.
	-- value	0.1	0.5	0.4	0.3	0.5	0.2	n.a.	n.a.
	All machinery -- value	n.a.	n.a.	1.0	1.0	1.0	1.0	n.a.	n.a.
	Total value of all imports	n.a.	n.a.	125	118	121	162	n.a.	n.a.
Ghana	Tractors -- quantity	421	918	299	911	349	1397	n.a.	n.a.
	-- value	26.7	32.6	9.2	40.1	25.9	62.1	n.a.	n.a.
	All machinery -- value	55.0	92.6	30.0	110.0	45.0	82.0	15.0[e]	n.a.
	Total value of all imports	3629	3942	3334	3649	3402	4482	n.a.	n.a.
Ivory Coast	Tractors -- quantity	413	498	291	n.a.	n.a.	n.a.	n.a.	n.a.
	-- value	37.5	49.8	31.7	n.a.	n.a.	n.a.	n.a.	n.a.
	All machinery -- value	n.a.	n.a.	33.0	58.0	88.0	61.0	n.a.	n.a.
	Total value of all imports	n.a.	n.a.	1465	1698	2450	2362	n.a.	n.a.
Kenya	Tractors -- quantity	820	253	416	809	790	902	n.a.	n.a.
	-- value	29.4	9.8	11.0	19.6	21.6	32.7	n.a.	n.a.
	All machinery -- value	55.0	44.0	18.0	30.4[f]	41.2[f]	47.7[f]	57.0[f]	65.5[f]
	Total value of all imports	1962	1930	1946	2063	2142	2493	n.a.	n.a.
Nigeria	Tractors -- quantity	467	413	233	319	783	n.a.	n.a.	n.a.
	-- value	22.9	24.2	16.6	14.7	23.3	19.5	n.a.	15.5[g]
	All machinery -- value	47.0[g]	39.0[g]	25.0	26.0	54.0	39.0	n.a.	31.6[g]
	Total value of all imports	6026	6216	5690	5809	7113	7716	n.a.	n.a.
Senegal	Tractors -- quantity	n.a.	n.a.	53	92	91	65	n.a.	n.a.
	-- value	7.9	12.7	3.2	6.4	7.4	4.3	n.a.	n.a.
	All machinery -- value	n.a.	n.a.	10.0	14.0	12.0	5.0	n.a.	n.a.
	Total value of all imports	n.a.	n.a.	1548	1561	1717	1643	n.a.	n.a.

(Table continued on next page.)

TABLE I.6 continued

Country	Item	1960	1961	1962	1963	1964	1965	1966	1967
Tanzania (Tanganyika & Zanzibar)	Tractors -- quantity	432	313	281	846	596	612	n.a.	n.a.
	-- value	14.2	14.8	6.5	19.5	23.1	21.5	n.a.	n.a.
	All machinery -- value	26.0	26.0	11.0	30.0	40.0	34.0	n.a.	n.a.
	Total value of all imports	1208	1287	1264	1282	1231	1401	n.a.	n.a.
Uganda	Tractors -- quantity	92	100	61	240	397	202	624[h]	n.a.
	-- value	4.4	2.7[i]	2.0	6.1	12.3	7.3	15.7[h]	n.a.
	All machinery -- value	12.0	2.8[i]	4.0	11.0	20.0	14.0	37.6[h]	n.a.
	Total value of all imports	729	743	734	865	918	1144	n.a.	n.a.

Source: (Where not otherwise stated) United Nations, *Trade Year Book* (Rome: Food and Agricultural Organization) Vol. XVI (1962), pp. 35-6; Vol. XVII (1964), p. 31; Vol. XVIII (1965), p. 55; Vol. XX (1966), p. 345 & pp. 400-414.

a. Data supplied by FAO Resident Representative in Addis Ababa.

b. Not available during course of the Study.

c. All values in U.S. $100,000.

d. Imperial Ethiopian Government, *Statistical Abstracts, 1966* (Addis Ababa: Central Statistical Office, 1967), p. 110.

e. Machinery only -- does not include tractors.

f. Republic of Kenya, Ministry of Economic Planning and Development, Statistical Division, *Kenya Statistical Digest* (Nairobi: Government Printer, 1968).

g. Federal Republic of Nigeria, Federal Office of Statistics, *Nigerian Trade Summary* (Lagos: Federal Ministry of Information Printing Division, December, 1967), p. 134.

h. Republic of Uganda, Ministry of Planning and Economic Development, Statistical Division, *1967 Statistical Abstract* (Entebbe: Government Printer, 1967), p. 23.

i. Interpolated.

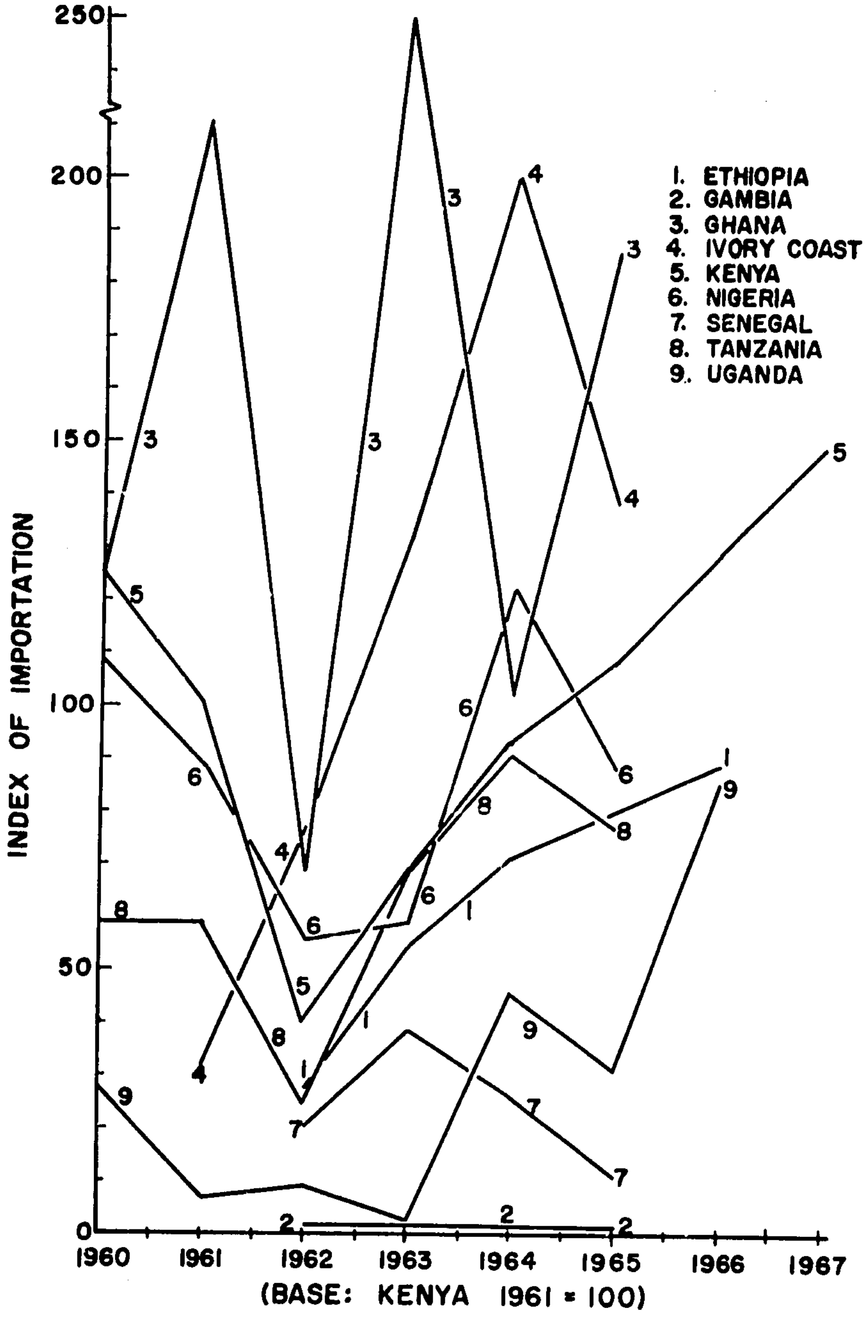

FIGURE 1.2 Indices of Agricultural Machinery Importations in Nine Equatorial African Countries

Ethiopia There has been a substantial increase in tractor imports but tractors comprise a diminishing proportion of total agricultural machinery imports which have increased slightly.

Gambia There has been a slight decline in agricultural machinery imports relative to total imports; the number of tractors imported has declined both in proportion to numbers in the country and in proportion to other agricultural machinery.

Ghana Although fluctuating, the proportion of total agricultural machinery imports tended to be constant; tractor proportions substantially increased with a tremendous boost in 1961.

Ivory Coast The relative value of agricultural machinery to other imports has remained fairly constant.

Kenya Agricultural machinery imports have gradually increased in relation to total imports, with a gradual increase in both the number of tractors imported and their proportion in total agricultural machinery imports.

Nigeria The relative proportions of both tractor and all agricultural machinery imports have remained at a constant low level among total imports; tractor imports ranged from about one-half to two-thirds of the total value of agricultural machinery imports.

Senegal The relative proportion of agricultural machinery imports to total imports remained fairly constant at a low level; there was a substantial increase in the value of tractor imports relative to the value of total agricultural machinery imports.

Tanzania Agricultural machinery imports remained a fairly constant proportion of total imports; tractor proportions of agricultural imports increased.

Uganda Agricultural machinery remained a fairly low percentage of total imports, tending to decline slightly; tractor imports were a substantial proportion of total agricultural machinery imports.

Selected Data on Engine Power

The schemes used to introduce tractors and engine-powered implements into the different countries have met with a variety of experiences. Most of the schemes were government sponsored; some isolated cases involved private enterprise.[30]

Selected data on tractor operational costs are presented in Table I.7. They are presented in tabular form for conciseness but not for exact comparison. They are, in fact, taken from a variety of agricultural conditions and

[30] The vast reservoir of skill, knowledge, and productive potential which lies dormant in the private sector of the economy is emphasized in the report of the President's Science Advisory Committee, *The World Food Problem*, Vol. I, p. 36.

types of schemes experienced during different working years and using different types of equipment. With the paucity of economic data on mechanization in Equatorial Africa this remains the best available information on tractor costs for comparing the experiences of different countries. Rough comparisons are permissible and small adjustments have been introduced to make the cost structures slightly more compatible. However, variability in methods of costing and the difficulty of putting data from different countries into a comparative basis make almost meaningless any attempt to relate capacities for similar operations in different countries.

Because these data are from widely scattered sources, accuracy is open to question and the lack of statistical significance in most cases leaves some doubt regarding the validity of general conclusions. Nevertheless, it is from these data and from similar information on field operational capacities that general conclusions are being drawn for future planning for lack of more systematic information. *The need to establish working procedures for recording operational data and the consciencious effort of those involved in record-keeping and cost accounting cannot be overemphasized.* Furthermore, cost estimates must be brought up-to-date frequently in order to accommodate price changes in expendable inputs and to relate operational costs to fluctuation in the prices of produce, especially in the export market. Depreciation charges vary widely and usually are correlated negatively to the number of annual operating hours for the tractor; this is an important factor in reducing the total operating costs for tractor operations.[31] In a number of cases operating hours were used as recommended by the manufacturers despite the fact that tractors are seldom used to full capacity in Africa. To calculate depreciation costs on a fictitious basis is misleading; attempts must be made to determine the actual number of working hours and the costs of operating agricultural machinery in particular situations.

The data presented in Table I.7 cover only a few isolated cases in each country. Cost items shown are roughly comparable. Data from most private farmers were not included because of a general failure to include administrative costs, but the two included private contractors in Kenya provided useful information.

Comparison of similar operations in different countries invites questions about the differences in costs. Such questions can be answered only by *careful comparative studies on the nature and conditions of operations and, at the same time, standardizing costing procedure as closely as possible between the countries.*

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[31] N.D. Wadhwa, "Improving of Efficiency on a Mechanized Farm", *The Ghana Farmer*, Vol. IX, No. 4, November, 1965, pp. 156-80.

The data so far under discussion represent, despite their broad sweep, a rough approximation of only about 3 to 4 percent of the entire agricultural area of the countries from which they have been derived.[32] The data on hand- and animal-powered farming come from a variety of case studies, independent and scattered observations of small-scale farmers. Despite the overwhelming numbers of small farmers, it is impossible to obtain a whole picture of any pattern of agriculture from the data available: the data are spotty and incomplete. *However, this sector of agriculture is so large that it cannot be ignored.*

Selected Data on Operating Hand and Animal Power

It is not easy to bring together comparable data on the farming operations of the small farmer. In the areas where hand labor is traditional much of the production data are given in terms of total labor requirements for each of the crops. From such information, the relative costs of production for different crops can be estimated in terms of total man-hours, but it is difficult to make comparisons between different operations within the productive process. Also, in a hand-labor economy it is the work potential of the total family which indicates the capabilities of the farm unit rather than the total number of persons in the farmer's family.[33] Thus, despite the possibility of establishing an average for observations, actual cultivation capacities vary widely between local families.

The data presented in Table I.8 are all drawn from Nigerian sources. The first four cases are from comparative experiments conducted by Shambaugh under experimental conditions. The fifth and sixth cases have been taken from Laurent's study of farming in northern Nigeria where the use of oxen has expanded quite dramatically:

> Between 1945 and 1956, the number of 'mixed' farms (those having oxen) increased from 2,400 to 15,000 and by 1965 there were an estimated 36,000 such farms.[34]

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[32]It has been estimated that the total agricultural area under tractor cultivation in Ethiopia amounts to about 3 percent of the total agricultural area of the country. (Institute of Agricultural Research, *A Preliminary Survey of Mechanized Farms in Ethiopia.*) In the case of Kenya the majority of tractors on private lands are employed on large scale farms which comprised 4.6 percent of total agricultural land in 1966. Republic of Kenya, Ministry of Economic Planning and Development, Statistics Division, *Statistical Abstract 1967* (Nairobi: Government Printer, August, 1967), pp. 72 and 79.

[33]C.J.N. Gibbs, *An Economic Study of Three Villages in Bauchi Province* (mimeographed) (Samaru, Nigeria: Ahmadu Bello University, Institute for Agricultural Research, Rural Economy Research Unit (RERU), August, 1968), pp. 10-12.

[34] C.K. Laurent, "The Use of Bullocks for Power on Farms in Northern Nigeria", *Bulletin of Rural Economics and Sociology*, Vol. III, No. 2, October, 1968, p. 235.

TABLE I.7 SELECTED DATA ON TRACTOR OPERATIONAL COSTS IN FIVE EQUATORIAL AFRICAN COUNTRIES

Description of tractor operation and costs (Item)	Ethiopia						Ghana		Kenya			
	1		2		3		4		5		6	
Year of operation	1967		1967		1967-9		1967-8		1964-5		1964-6	
Tractor size (engine h.p.)	50-60 h.p.		50-55 h.p.		50-55 h.p.		50 h.p.		35-40 h.p.		35-40 h.p.	
Operational hours per tractor per year	1500		750		1400		1600		729		1137	
Running Costs	Dollars per hour and percentage of running costs											
	$	%	$	%	$	%	$	%	$	%	$	%
Fuel, oil and grease	0.83	32.2	0.52	22.60	0.97	39.8	0.69	46.3	0.47	20.9	0.34	23.1
Spares, repairs and maintenance	0.66	25.4	0.57	24.9	0.56	22.9	0.27	18.1	0.55	24.4	0.34	23.1
Driver's wage	0.72	27.7	0.40	17.3	0.19	7.8	0.19	12.8	0.46	20.5	0.30	20.5
Total direct costs	2.21	85.3	1.49	64.8	1.72	70.5	1.15	77.2	1.48	65.8	0.98	66.7
Depreciation	0.38	14.7	0.81	35.2	0.72	29.5	0.34	22.8	0.77	34.2	0.49	33.3
Total running costs	2.59	100.0	2.30	100.0	2.44	100.0	1.49	100.0	2.25	100.0	1.47	100.0
Overhead Costs	Dollars and percentage of total costs											
	$	%	$	%	$	%	$	%	$	%	$	%
Supervision and administration costs	-	-	0.40	14.7	-	-	0.22	9.0	1.73	43.5	1.11	43.0
Interest and insurance	0.02	0.7	0.02	0.7	0.32	11.6	-	-	-	-	-	-
Travel costs	0.31	10.6	-	-	-	-	0.75[b]	30.5	-	-	-	-
Total overhead	0.33	11.3	0.42	15.4	0.32	11.6	0.97	39.5	1.73	43.5	1.11	43.0
Total costs per operational hour	2.92	100.0	2.72	100.0	2.76	100.0	2.46	100.0	3.98	100.0	2.58	100.0

Notes

[a]Estimated from available information, data not specifically stated.

[b]Transport costs based on 50 percent of total running costs.

TABLE I.7 continued

Description of tractor operation and costs (Item)	Kenya						Nigeria		Tanzania	
	7		8		9		10		11	
Year of operation	1965-6[a]		1965-6[a]		1967-8		1966-7		1967	
Tractor size (engine h.p.)	6 x 55 h.p. 1 x 35 h.p.		55 h.p.		56-8 h.p.		40 h.p.[a]		35-58 h.p.[a]	
Operational hours per tractor per year	1500		804		772.4		535		600	
Running Costs	- - - - -Dollars per hour and percentage of running costs- - - - - -									
	$	%	$	%	$	%	$	%	$	%
Fuel, oil and grease	0.89	45.2	0.84	34.0	0.94	20.8	0.46	15.5	1.34	48.9
Spares, repairs and maintenance	0.24	12.2	0.35	14.2	0.92	20.3	0.49	16.5	0.46	16.8
Driver's wage	0.28	14.2	0.47	19.0	1.21	26.8	1.06	35.7	0.35	13.8
Total direct costs	1.41	71.6	1.66	67.2	3.07	67.9	2.01	67.7	2.15	78.5
Depreciation	0.56	28.4	0.81	32.8	1.45	32.1	0.96	32.3	0.59	21.5
Total running cost	1.97	100.0	2.47	100.0	4.52	100.0	2.97	100.0	2.74	100.0
Overhead Costs	- - - - - - - Dollars and percentage of total cost- - - - - - -									
	$	%	$	%	$	%	$	%	$	%
Supervision and administration costs	0.40	15.8	0.56	18.5	0.64	12.4	0.47	13.5	0.17	5.1
Interest and insurance	0.16	6.3	-	-	-	-	0.04	1.2	0.43	12.9
Travel costs	-	-	-	-	-	-	-	-	-	-
Total overhead costs	0.56	22.1	0.56	18.5	0.64	12.4	0.51	14.7	0.60	18.0
Total costs per operational hours	2.53	100.0	3.03	100.0	5.16	100.0	3.48	100.0	3.34	100.0

(For column identification, see next page.)

Column number

1. Awash Valley Authority, Middle Awash Settlement Scheme, cost estimates based on operating four wheel-tractors.
2. Cost estimates employed by the Institute of Agricultural Research, Addis Ababa.
3. Tendaho Plantations Share Company, cost estimates based on operating 50 wheel-tractors.
4. Government of Ghana, Ministry of Agriculture Transport Division, cost estimate based on operating 892 wheel-tractors.
5. Sabatia Settlement Complex, cost estimates based on operating five wheel-tractors. International Bank for Reconstruction and Development, Permanent Mission in Eastern Africa, *Agricultural Mechanization in East African Countries*, Table 4A.
6. Eburru Settlement Complex, cost estimates based on operating five wheel-tractors. *Ibid.*
7. Private contractor, cost estimates based on operating 6x55 h.p. wheel-tractors and 1x35 h.p. wheel-tractor. *Ibid.*, Table 6B.
8. Private contractor, cost estimates based on operating one wheel-tractor. *Ibid.*
9. Ministry of Agriculture, Tractor Hire Service, cost estimates based on operating 50 wheel-tractors on basic tillage and planting operations. C.M. Downing, *Tractor Hire Service Report and Evaluation, Financial Year 1967/68* (mimeographed) (Nairobi, Ministry of Agriculture, October 18, 1968) and C.M. Downing, *Wheat Cultivation Trials, Oloscos 1967-68* (mimeographed) (Nairobi, Department of Agriculture, April 16, 1968).
10. Ministry of Agriculture and Natural Resources, Tractor Hire Units, cost estimates based on five Tractor Hire Units serving 75 farmers in western Nigeria. Malcolm J. Purvis, *op.cit.*
11. Cost estimates based on cotton block farms operation for 1967. "G. H.", *Notes on Costings of Cotton Block Cultivation, Tanzania* (mimeographed), Report to Ministry of Agriculture by Massey Ferguson Company (January 1967).

TABLE I.8 SELECTED COMPARISON OF HAND-, OXEN-, AND MACHINE-CULTIVATION PRACTICES

	1	2	3	4	5	6
Type of Implement	Short handled hoe	4 h.p. rotary cultivator (5.6 meters wide)	50 h.p. tractor and 2-row power take-off cultivator (1.8 meters wide)		One pair of oxen with ridging plow	
Rate of operation			6.08 km./hour (first gear)	10.08 km./hour (second gear)	0.81 hectares per 8 hour day	
Hours per hectare	43.19	4.65	0.89	0.54	9.88	9.88
Hectares per hour	0.023	0.22	1.13	1.82	0.101	0.101
Wage rate per hour ($)	0.07	0.088	0.117	0.117	0.07	0.07
Operator	1 hand-laborer	1 driver	1 driver	1 driver	1 plow man	2 plow men
			dollars per hectare			
Operating costs (per hectare)						
Fuel	-	0.41	0.19	0.08	-	-
Repairs, maintenance and depreciation	-	0.39	0.42	0.25	3.25	3.25
Wages	1.22	0.16	0.04	0.03	0.69	1.38
Total operating costs	1.22	0.96	0.65	0.36	3.94	4.63
			dollars per hour			
Operating costs (per hour)						
Fuel	-	0.22	0.59	0.36	-	-
Repairs, maintenance and depreciation	-	0.21	1.16	1.16	0.33	0.33
Wages	0.07	0.08	0.12	0.12	0.07	0.14
Total	0.07	0.51	1.87	1.64	0.40	0.47

Column number

1/2/3/4 T.J. Shambaugh, *Comparison of Hand- and Machine Cultivation Costs* (mimeographed) Special Report No. 64-5, (Maiduguri, Nigeria: Industrial Development Center, September, 1964). These are specially designed field tests rather than observations of actual farming practices.

5/6 C.K. Laurent, *op. cit.*, pp. 244-5.

Taken from approximately the same farming area, these sets of data are useful in illustrating that cultivation costs are low for hand- and animal-powered cultivation when compared on an hourly basis with engine-powered operations. In contrast, since engine-powered equipment is able to operate much more rapidly over a given area, engine-powered equipment appears lower on the basis of costs per unit area of operation. However, this comparison lacks strict validity since the *farmer using oxen has to cover all depreciation and maintenance costs for animals and equipment over the entire season, whereas tractor operations are charged only for depreciation and maintenance over the time taken for the particular operation,* assuming an efficient total working life for the tractor of 5000 hours. *Nor is this kind of comparison strictly useful without some indication of the economic returns which can be expected from each type of cultivation,* and the area restrictions on cultivation for the different systems.

In considering the small farmer with hand- or animal-powered equipment, it is important to realize that capital acquisition costs are the main criterion in determining whether it can be economically possible for him to move into a form of engine-powered technology. The use of engine-powered equipment is only economical if it can be used efficiently throughout its working life in order to spread depreciation (amortized acquisition costs) and maintenance costs over a substantial increase in the volume of production. There is a maximum limit to the area which any farmer can cultivate by hand or animal power; in contrast, the minimum limit below which engine power is uneconomical is generally a larger area than most small farmers can acquire or manage. The availability of time is generally a less critical factor than the availability of capital or land; or where land is not scarce, increasing the area of land frequently creates management problems beyond the skills of the small farmer to handle. Thus, costs on a basis of time tend to be more significant than costs on the basis of unit area in considering the choice of cultivation practices open to the small farmer, even though timeliness of cultivation may be less certain.

With those general constraints on the small farmer of capital availability, size of operation, and management ability, the lower cost of hand- and/or animal-powered equipment is significant in inhibiting change to an engine-powered technology. Where engine-powered equipment can overcome problems of timeliness, or bottlenecks in the productive processes to permit the small farmer to expand the size of his operation, then the constraints of capital and management ability can be overcome by making available appropriate equipment and management assistance. Hence, there emerges in certain situations the rationale for tractor-hire and block farm schemes with appropriate extension services.

Additional data are available which further illustrate that hand- and animal-powered farming are not always the least expensive or the most economical modes of farming under African conditions.[35] Operational tractor capacity keeps the costs of tractor cultivation substantially lower than cultivation by other methods. However, such data must be related to the economic returns of crop output prior to the decision-making process of economic planning and farm management.

The conclusion is invited that employing tractor power is economical, but caution must be exercised in generalizing from such cases as these. The underlying assumption in this example that hand labor costs about $0.12 per man-hour is valid only if a worker has to be hired or a self-employed farmer has a positive opportunity cost approaching this value. In many cases there is no alternative employment for the small farmer so the opportunity cost for his own hand labor approaches zero. Therefore, an imputed value for labor such as in this example may lead to invalid generalizations.

In several parts of this report data is presented which is based on imputed labor values. No attempt has been made to determine whether or not the assumed cost of hired labor reflects the marginal productivity of the worker. The data is presented in terms of actual wages paid by responsible employers in the area in which the observations were made. Where comparisons are made between similar operations in different areas two reservations must be made with respect to such data:

1. *That the imputed value of labor varies significantly between different areas within a country, and between countries; and*

2. *That there is considerable difference between the actual cost to hire labor and the cost of a farmer and his family's labor on their own farm.*

Having recognized that a local going wage rate does not usually reflect the cost of labor for a given operation in a given area for the majority of small farmers, the problem of selecting an appropriate wage rate remains. The necessary information available directly to the team was that from individuals who were actually paying wages. These rates have been used and statements giving the source of the information have been included with the data.

Objectives of the Study

Contributions to the preparation of this report have originated from the Agricultural Engineers, the Agronomist and the Agricultural Economist. The following objectives have guided the work of the Team in their individual

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[35] V.A. Oyemga, "Comparative Costs and Time Required to Plant and Fertilize One Acre of Groundnut, by Hand, Bullock-drawn Planter and Tractor Planter in Ghana in 1959", *Agriculture in Nigeria* (Rome: Food and Agricultural Organization of the United Nations, 1967), Table 11.2, p. 277.

approaches from the standpoint of their separate disciplines:

1. To identify and analyze farming methods now followed and the types of tools and equipment now used;

2. To identify the factors or conditions favoring or hindering various forms of mechanization;

3. To make an economic appraisal of the problems inherent in selective mechanization in the areas studied;

4. To identify specific agricultural engineering problems requiring attention and suggest related research; and

5. To develop a series of generalizations as the basis for planning selective mechanization programs.

Equatorial Africa is on the verge of rapid expansion in the use of all forms of improved mechanical power. The path ahead undoubtedly will be marked with both false starts and encouraging successes in mechanization and other agricultural innovations. Both failures and successes should be studied objectively to avoid the former and to insure the latter.

Methodology

The presented data and discussions have emanated from field work, published and unpublished research and correspondence with other workers in the field. The field work, in which the Agricultural Engineer and the Agronomist were involved in Africa for about a year and a half, joined by the Economist for a shorter period of a little less than a year, constituted Phase II of the Study. During Phase II the Team members worked closely with African farmers, agricultural officials, planners, economists, sociologists, anthropologists, educators and others assigned to local government or foreign technical assistance programs.

An indispensable part of the Study was firsthand experience in the field of a selected number of mechanization endeavors. Such knowledge cannot be gained in any other way and it affords the opportunity to discuss and exchange information with professional persons directly involved in the process of agricultural mechanization. Such experience generates caution against generalizations from isolated observations or sources of information; moreover, such direct participation helps the investigator examine the validity of any generalizations. The methodology of the Study was substantially one of gathering information and critically examining the actual personal experiences of relevant individuals.

Two countries were selected for depth studies: Ethiopia and Ghana. Since the Team members resided in Addis Ababa they became more familiar with the agriculture of Ethiopia. In addition, easy access to rural areas facilitated by available transport and contacts through the Institute of Agricultural Research, the USAID mission and other technical assistance agencies, allowed

more specific observations and collection of data possible in Ethiopia. Five study sites were selected in Ethiopia (Figure 1.3)[36] and these circumstances partially influenced the methodology of the Study in the data presented to represent different farming systems. The method of approach to each farming system has been to employ the experience and data from the Ethiopian situation as a point of departure to compare and contrast the situation in other countries.

The mechanization of Equatorial African agriculture involves two pairs of parallel and simultaneous lines of approach, inseparable in the process of working out policy recommendations. First, there is the socio-technical line of introducing a mechanized agricultural technology either through the medium of large-scale commercial agricultural enterprises or through attempts to modify the traditional technologies of small-scale farmers who have organized the productive processes of their farms to meet their families' needs. These extended families are large, their members usually live in close proximity, and often have been in the same locality for many generations. The needs of all members of the family are a vital concern to the small farmer and have great influence on the way he organizes his farm. Second, there is the political-technical line of introducing a mechanized technology into the patterns of national agricultural through the development of both national agricultural policies, having the objective of improving national agricultural productivity, and international (regional) agricultural policies, having the objective of sharing research facilities and knowledge.

Recommendations and guidelines are presented in Part 1, the first ten are related to the development of national policies for agricultural mechanization. There are corresponding guidelines which relate to the social and technical details of implementing the recommendations. Recommendation XI is specifically related to the development of regional cooperation and Guideline XI contains more specific details for the development of such international cooperation. Recommendation XII and its accompanying guideline are related to the development of textbooks to improve the fund of available knowledge on African agriculture, a regional approach to the problem is also incorporated in these.

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[36]Maps of each country (Figures 1.3 to 1.6) are included at the end of Chapter I. Each map shows the capital, some of the country's principal towns, rivers and railways, and the areas of work visited by the Study team.

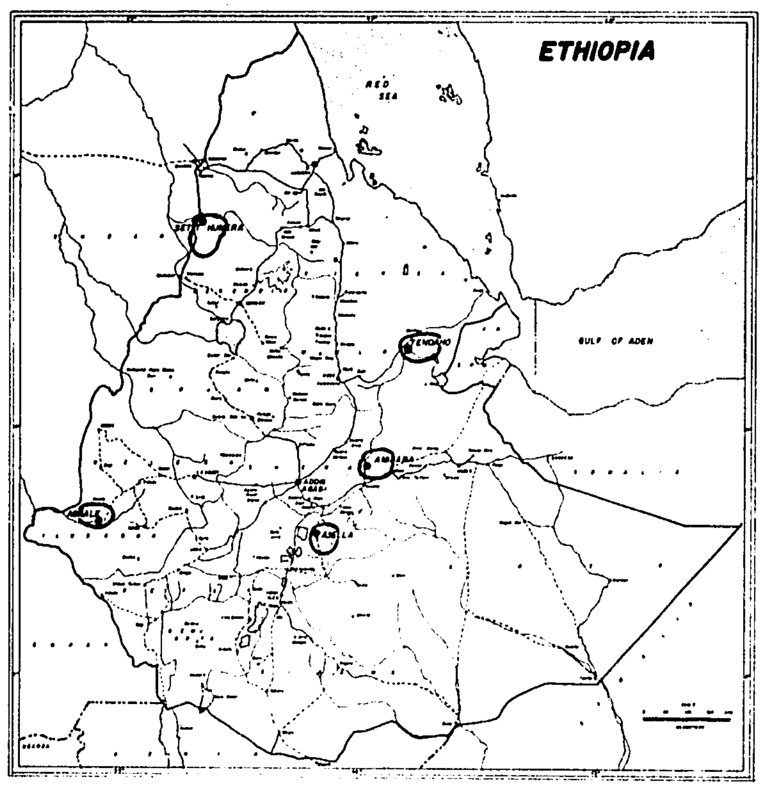
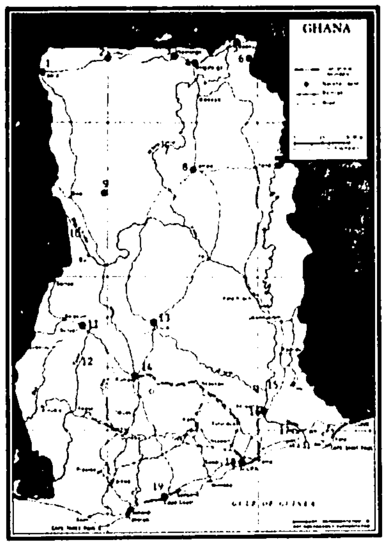


FIGURE 1.3 Five Selected Study Sites in Ethiopia Each study site represents a system of agriculture utilizing a different level of mechanization. Agnale: village close to the Pokwo mission station, the least sophisticated hand-tool system; Asella: the principal town in the Chilalo Awraja, an area in transition between animal- and engine-powered agriculture; Amibara: the Middle Awash Settlement Scheme employing hand labor and engine-powered implements; Tendaho: a large-scale commercial plantation employing hand labor and engine-powered equipment; Setit-Humera: large scale private entrepreneurs employing hand labor and engine-powered equipment.

GHANA

1. Lawra
2. Tumu
3. Navrongo
4. Bolgatanga
5. Bawku
6. Garu
7. White Volta River
8. Tamale
9. Damongo
10. Black Volta River
11. Sunyani
12. Tano River
13. Ejura
14. Kumasi
15. Lake Volta
16. Akosombo
17. Volta River
18. Accra
19. Cape Coast



IVORY COAST

1. Korhogo
2. Man
3. Bouake
4. Daloa
5. Yamoussoukro
6. Abengourou
7. Bandama River
8. Comoe River
9. Sassandra
10. Abidjan
11. Grand-Bassam

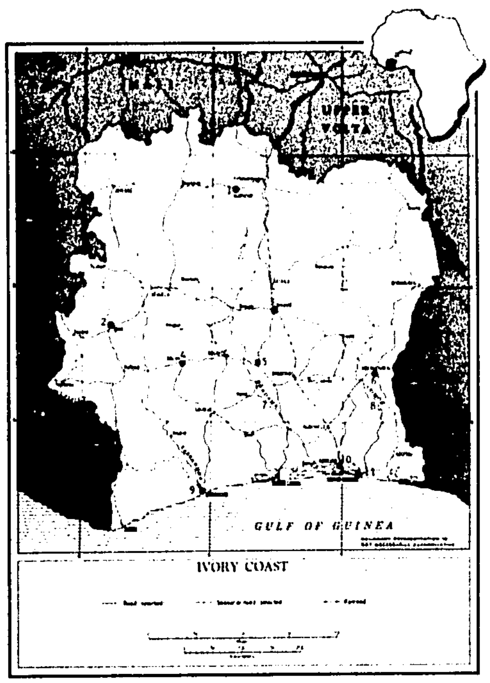
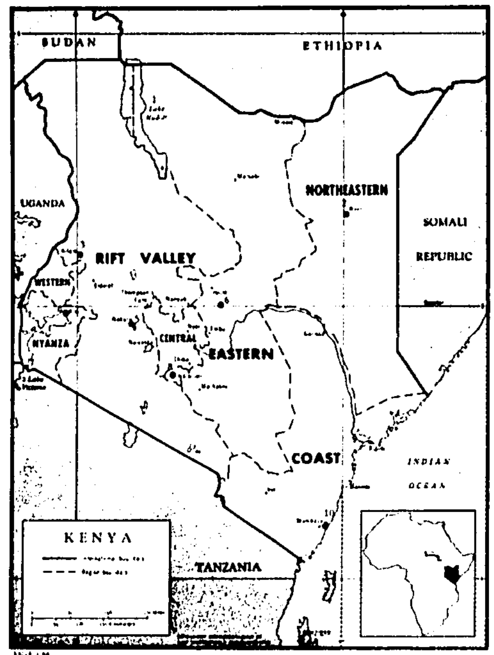
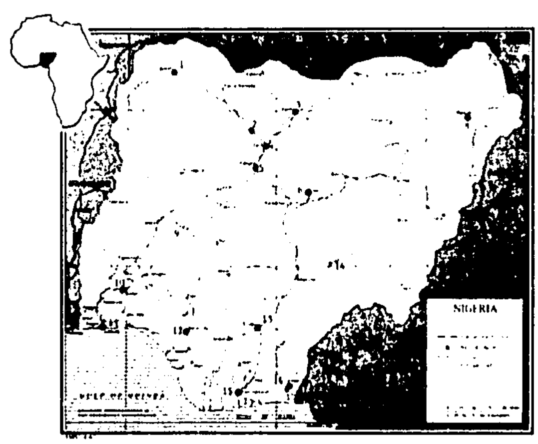


Figure 1.4 Maps of Ghana and Ivory Coast Maps show principal towns, rivers, railways and areas visited by the Study team.

KENYA

1. Lake Rudolf
2. Wajir
3. Kitale
4. Kisumu
5. Nakuru
6. Meru
7. Lake Victoria
8. Nairobi
9. Tana River
10. Mombasa





NIGERIA

1. Sokoto
2. Samaru
3. Kano
4. Zaria
5. Kaduna
6. Jos
7. Lake Chad
8. Maiduguri
9. Niger River
10. Ibadan
11. Lagos
12. Benin City
13. Enugu
14. Benue River
15. Port Harcourt
16. Calabar

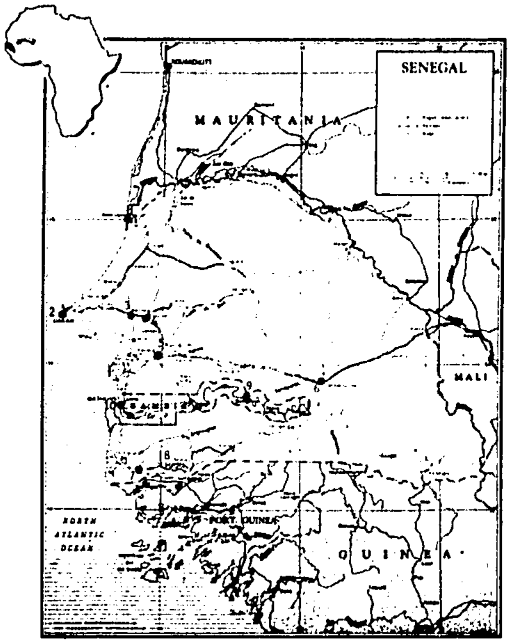
Figure 1.5 Maps of Kenya and Nigeria Maps show principal towns, rivers, railways and areas visited by the Study team.

SENEGAL

1. St. Louis
2. Dakar
3. Bambey
4. Diourbel
5. Kaolack
6. Tambacounda
7. Ziguinchor
8. Casamance River

GAMBIA

9. Georgetown
10. Bathurst



TANZANIA

1. Lake Victoria
2. Mwanza
3. Shinyanga
4. Kigoma
5. Tabora
6. Lake Tanganyika
7. Arusha
8. Tanga
9. Zanzibar
10. Morogoro
11. Dar es Salaam
12. Mbeya
13. Rufiji River
14. Mtwara

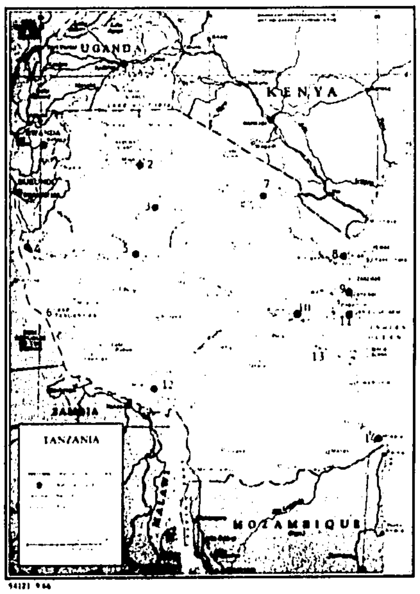


Figure 1.6 Maps of Senegal and Gambia, and Tanzania Maps show principal towns, rivers, railways and areas visited by the Study team.

CHAPTER II

GENERAL DESCRIPTION OF PRESENT FARMING SYSTEMS IN SELECTED EQUATORIAL AFRICAN COUNTRIES

Introduction: Interrelated Factors of Mechanization

The process of agricultural mechanization requires incremental introductions of capital into the production function. Basically, the agricultural production function combines land, labor and capital in a manner supervised by the farmer acting in his role as manager. The nature of changes in the production function depends on the intended function of the newly introduced capital.

Capital invested in labor-saving equipment becomes a substitute for labor and is considered a labor-saving technological change. Conversely, agricultural equipment which facilitates improved cultivation without displacing manpower, becomes a substitute for land, therefore a land-saving technological change. A change involving capital as a substitute for neither land nor labor is a neutral technological change. This latter form of change can raise the level of productivity of all factors.

Comprehension of the effects of mechanization and the possibilities for successfully effecting such changes requires a full description of the systems of farming into which the changes of mechanization may be introduced. This chapter describes examples of the systems studied during the course of field observations in Equatorial Africa.

Each system discussed may be considered as the basis for subsequent model building. Three broad categories of farming systems are identified although it is not always easy to maintain a strict division between the systems. Difficulties are created by examples being taken from contemporary dynamic situations themselves caught up in the process of change. These three categories are: hand-powered agriculture, animal-powered agriculture and engine-powered agriculture.

In addition to the immediately apparent technology incorporated into the socio-economic agricultural system, there are also critical ecological factors of climate and soils to be taken into account. A brief introductory section on soil and climate observations made in Ethiopia precedes the description of selected farm systems. These data are limited to actual observations at the study sites in Ethiopia only; they serve to demonstrate the ecological data to be taken into account in developing any proposals for mechanization schemes.

Ecological Factors

Mechanization is a responsive factor for increasing agricultural productivity only if the ecological factors of climate and soils are not principal

limiting factors for increasing crop production. *The cost of any new mechanization system must be met primarily by the value of the increase in crop production resulting from using the new system.* This means that rainfall or irrigation must be adequate for increases in crop production; it also implies that the potential productivity of the soils is adequate to produce larger crop yields. Both of these ecological factors are assessed for the intensive study sites in Ethiopia.

Rainfall at the Ethiopian Study Sites[1]

Average annual rainfall, elevation, and dominant soils are listed for the five study sites in Ethiopia in Table II.1. The 900 to 1,000 mm. of annual rainfall at the Pokwo site (Agnale Village) appears adequate for at least two rain-fed crops a year of maize (corn), grain sorghum and edible beans and peas. Proximity to the Baro River guarantees a good irrigation potential but so far no irrigation has been practiced. At the CADU site, the 700 to 1,000 mm. of annual rainfall seems adequate for the production of rain-fed wheat, barley and edible beans and peas. The annual rainfall of 350 to 450 mm. at Amibara is not sufficient to grow any rain-fed crop, but proximity to the Awash River makes irrigation potential satisfactory. With irrigation, cotton production has been very successful, and maize (corn) serves as a good food grain for use by the Afar (Danakil) people for whom the Middle Awash Settlement Scheme (Amibara) has been planned. At the Setit-Humera site, the 500 to 700 mm. of annual rainfall seems to be adequate for one rain-fed crop a year of cotton, grain sorghum and sesame.

TABLE II. 1 AVERAGE ANNUAL RAINFALL, ELEVATION, AND DOMINANT SOILS AT FIVE ETHIOPIAN STUDY SITES

Study Site	Average Annual Rainfall	Elevation	Dominant Soils
	millimeters	meters	
Pokwo (Agnale Village)	900 to 1,000	1,800	Silty and clayey alluvium from Baro River
Chilalo Agricultural Development Unit (CADU)	700 to 1,000	2,000 to 2,500	Dark brown clays developed from calcareous lava and bedrock; some red, acid clays
Amibara	350 to 450	750	Silt loams and clay loam alluvium from Awash River
Tendaho	100	400	Silty and clayey alluvium from Awash River, some saline
Setit-Humera	500 to 700	500 to 700	Vertisols (deep, black, residual clays)

[1]Figure 2.1 shows average annual precipitation in the African continent.

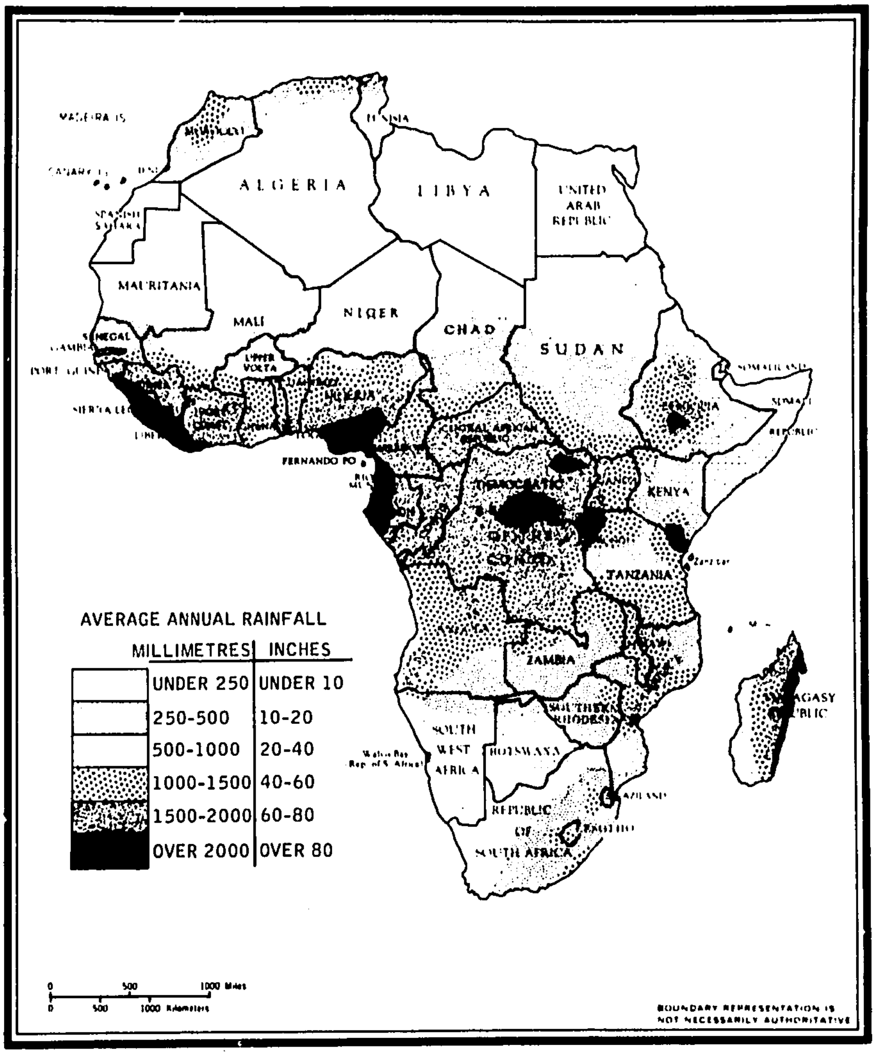


Figure 2.1 <u>Average Annual Precipitation in Africa</u>
Source: Nels M. Konnerup, "The Outlook for Animal Agriculture in Africa", National Research ouncil. Agricultural Research Institute, *roceedings of the Fifteenth Annual General eeting* (Washington, D.C., October 10-11, 1966), p. 137. (692217-3)[a]

[a]Negative number filed at Michigan State University Photographic Laboratory, East Lansing, Michigan 48823.

Soils at the Ethiopian Study Sites

From the air and soil, crop plants absorb 16 elements essential for growth and reproduction of which 13 originate in the soil. All of the elements must be available to the plant continuously in balanced form, and a deficiency of any one element will limit plant growth. Plant growth may also be restricted by either an excess or a deficiency of soil water or an excess of soluble salts.

To assess the productivity potential of the intensive study sites in Ethiopia, field descriptions of each site and of each soil profile were made on standard forms, "SCS-232C-Soil Description, GPO 874130-352259". The number of soil pits dug and the number of soil samples taken from the exposed profiles for physical and chemical analyses are given in Table II.2.

TABLE II.2 NUMBERS OF SOIL PITS AND SAMPLES TAKEN AT FIVE ETHIOPIAN STUDY SITES

Study Site in Ethiopia	Number of Soil Pits	Number of Soil Samples Taken and Analyzed
Pokwo (Agnale Village)	6	19
CADU	5	30
Amibara	5	25
Tendaho[a]	n.a.	n.a.
Setit-Humera	13	84
Total	29	158

[a]Soil sampling and soil analyses at Tendaho Plantations were contracted to a commercial company in the United Kingdom.

At the intensive study sites of Agnale, CADU, Amibara and Setit-Humera, soil pits were dug measuring 1 meter wide, 2 meters long and 2 meters deep, following the procedure recently recommended by the U.S. Department of Agriculture.[2] At each of the sites of the soil pits, study activities included:

1) Recording the topography, elevation, rainfall, water table, crop or other vegetation present, aspect, degree of erosion, permeability, presence of salt or alkali, and the stoniness of the area and of the soil profile;

2) Describing the soil horizons and recording their depth, moisture content, Munsell color designation, texture, structure, consistence, and calcareousness. Depth of rooting was also recorded;

3) Taking soil samples from each recognizable horizon or at predetermined depth for physical and chemical analyses.

[2]"Soil Sampling. Take samples from freshly dug pits and not from road cuts. Where possible, dig the pit to at least 5 feet /150 cm./ and deeper if necessary."

U.S. Department of Agriculture, *Soil Survey Laboratory Methods and Procedures for Collecting Soil Samples*, Soil Survey Investigations Report No. 1, Soil Conservation Service (Washington, D.C.: U.S. Government Printing Office, 1967), p. 5.

The laboratory determinations made by the Institute of Agricultural Research included: the percentage of sand, silt and clay; acidity tests (pH); available phosphorus, organic carbon, total carbonates; and conductivity (soluble salts).

Soils at Pokwo (Agnale Village)

Productivity potential of 19 soil samples from six soil pits in the Pokwo/Agnale area is indicated in Table II.3.

Rooting depth of 150 to 200 cm. is satisfactory; high to medium in soil organic matter is favorable; soil textures of clay loam are not in any way a deterrent to good crop production; slight to moderate acidity is favorable for most crops; the high available phosphorus is desirable; and a generally low salt content is satisfactory for crop production. (Only one 0-5 cm. surface soil sample tested high in soluble salts; this was probably because crop residues had been burned in a pile near the area sampled.) To summarize: the soils near Pokwo/Agnale, along the banks of the Baro River, are the most favorable for crop production of any soils tested from the study sites in Ethiopia. (Figures 2.2 and 2.3)

Soils at CADU

The productivity potential of 30 soil samples from five soil pits in the Chilalo Agricultural Development Unit are given in Table II.4. In addition, a soil test comparison is shown for a burned soil and an unburned one nearby.

Rooting depths are from 150 to 200 cm.; organic matter is from low to high (very high in all surface soils); textures vary from loam to clay, averaging a clay loam; acidity varies from slightly acid to alkaline; available phosphorus is from low to high; and salt content averages medium. There are no limiting factors for crop production indicated by these analyses. (Figures 2.4 and 2.5.)

Many farmers in the area burn black clay soils when preparing for a crop following several years of fallow. As shown in Table II.4, burning decreases organic matter, makes the Bouyoucos hydrometer method of mechanical analysis wrongly indicate a "loamy sand" instead of a "clay loam", makes a moderately acid soil neutral, and increases available phosphorus by 385 percent. *These tests indicate that probably the primary reason for burning the black clay soils is to make the soil phosphorus more readily available.* In the 20th Century, it would be more economical to apply phosphorus fertilizer.

Physical and chemical analyses have been made on 26 surface soil samples from Chilalo Awraja (subprovince) by the late H.F. Murphy of Oklahoma State University, and the data pertinent to the Study follows in Table II.5.

TABLE II.3 PRODUCTIVITY POTENTIAL OF SOILS IN POKWO/AGNALE TO THE ROOTING DEPTH INDICATED (Average of 19 soil samples from six soil pits.)

Soil Profile No.	Rooting Depth	Organic Matter a/	Soil Texture	Soil Acidity b/	Available Phosphorus c/	Salt Content (conductivity) d/	Vegetation or Crop
	cm.						
I	160	high	clay loam	moderately acid	high	high to low	maize (corn)
II	200	high	clay loam	slightly acid to neutral	high	low	grain sorghum
III	150	high	sandy clay loam	slightly acid	high	low	grain sorghum
IV	200	high	sandy clay loam	slightly acid	high	low	maize (corn)
V	200	high to medium	sandy clay loam	slightly acid	high	low	maize (corn)
VI	200	high to medium	clay loam	slightly acid	high	low	large trees and elephant grass

[a]Soil organic matter ratings are: high, above 2.0%; medium, 1.0-2.0%; low, less than 1%.

[b]Soil acidity (pH) ratings: very strongly acid, 4.0-5.0; strongly acid, 5.0-5.5; moderately acid, 5.5-6.0; slightly acid, 6.0-6.7; neutral, 6.7-7.2; weakly alkaline, 7.2-8.0; alkaline, 8.0-9.0; strongly alkaline, 9.0-10.0; excessively alkaline, 10.0-11.0.

[c]Available phosphorus (mg. of P_2O_5 per 100 g. of soil) ratings: high, above 2.0; medium, 0.4-2.0; low, below 0.4.

[d]Salt content (conductivity $1x10^{-3}$ reciprocal mhos per cm.) ratings: excessive, above 1.5; high, 0.8-1.5; medium, 0.2-0.8; and low, below 0.2.

Figure 2.2 Pokwo (Ethiopia): Soil pit at the mission station
Along the banks of the Baro River the soils are the most favorable for crop production of any soils tested from study sites in Ethiopia. Maize (corn) growing in a clay loam has a rooting depth of 150 to 200 cm. (AFR-75)[a]

Figure 2.3 Agnale village (Ethiopia): Soil pit 15 kilometers downstream from Pokwo Soils are observed growing grain sorghum. Very fertile clay loam soils have good potential for growing tropical and semi-tropical crops. Communications and distance from a potential market are serious factors inhibiting the development of the area.(AFR-76)

[a]Negative number, filed in Agricultural Engineering Department, Michigan State University, East Lansing, Michigan 48823.

TABLE II.4 PRODUCTIVITY POTENTIAL OF SOILS IN CHILALO AGRICULTURAL DEVELOPMENT UNIT TO THE ROOTING DEPTH INDICATED (Average of 30 soil samples from five soil pits.)

Soil Profile No.	Rooting Depth cm.	Organic Matter[a]	Soil Texture	Soil Acidity[b]	Available Phosphorus[c]	Salt Content (conductivity)[d]	Vegetation or Crop
I	150	high	loam to clay loam	weakly alkaline	medium	medium	onion/wheat
II	190	low to high	loam to clay	neutral to alkaline	low to high	medium	wheat
III	160	low to high	clay loam to clay	neutral to alkaline	medium	medium	wheat
IV	200	low to high	clay loam	slightly acid to weakly alkaline	low to medium	low to high	wheat
V	150	medium to high	clay loam to clay	slightly acid to neutral	low to medium	medium	barley
Near Profile V (0-15 cm.)	Burned	low	loamy sand	neutral	18.45	medium	barley
	Unburned	high	clay loam	moderately acid	3.81 (mg./100g. soil)	medium	barley

[a]Soil organic matter ratings: high, above 2.0%; medium, 1.0-2.0%; low, less than 1%.

[b]Soil acidity (pH) ratings: very strongly acid, 4.0-5.0; strongly acid, 5.0-5.5; moderately acid, 5.5-6.0; slightly acid, 6.0-6.7; neutral, 6.7-7.2; weakly alkaline, 7.2-8.0; alkaline, 8.0-9.0; strongly alkaline, 9.0-10.0; excessively alkaline, 10.0-11.0.

[c]Available phosphorus (mg. of P_2O_5 per 100 g. of soil) high, above 2.0; medium, 0.4-2.0; low, below 0.4.

[d]Salt content (conductivity $1x10^{-3}$ reciprocal mhos per cm.) ratings: excessive, above 1.5; high, 0.8-1.5; medium, 0.2-0.8; and low, below 0.2.

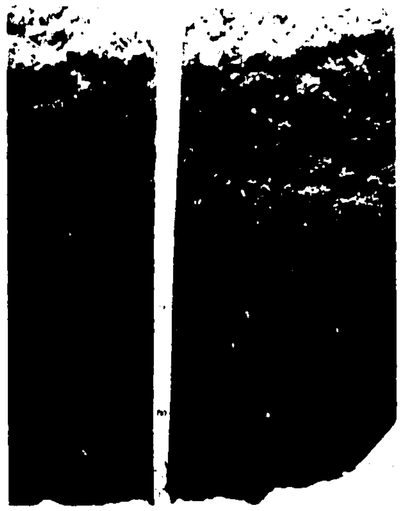


Figure 2.4 Asella (Chilalo Awraja, Ethiopia): Black clay soils
Soils on which wheat or barley are usually grown are shown here in a pit dug to a depth of 180 cm. The soil here is deep and fertile. (AFR-147)

Figure 2.5 Asella (Chilalo Awraja, Ethiopia): Soil burning The same fertile black clay soils shown in Figure 2.4 are usually burned at the time they are plowed, after lying fallow for several years. Reasons offered for burning are: (1) to destroy sod pieces and old roots, (2) to kill insects, and (3) to increase fertility. Inputs such as proper tillage implements, insecticides, and fertilizers may replace soil burning. Research is needed on this subject. (AFR-148)

TABLE II. 5 SOME PHYSICAL AND CHEMICAL PROPERTIES OF SURFACE SOILS FROM CHILALO AWRAJA[3]

Clay	Organic Matter	Soil pH		Available Phosphorus	Available Potassium	
percentage of soil samples testing						
Between 50% and 87%	Between 5% and 13.5%	Between pH 5.5 and 6.4	Between pH 6.5 and 7.1	Low	High	Medium
62	73	82	18	100	82	18

Soil management problems that are indicated by these analyses are:

1. With such a high percentage of clay in so many soils, downward movement of water is likely to be slow, thus forcing more water to flow across the surface of the soil and cause erosion; or to become impounded and delay the planting of crops. Furthermore, impounding of water causes 'osses of soil nitrates by denitrification.

2. High percentages of organic matter are desirable for soil filth and crop production.

3. So many soils below pH 6.4 would indicate a need for starting experiments on the use of lime, but with such a high clay percentage this would be of doubtful value.

4. Low available phosphorus indicate. that at least the bean crops should respond to some form of phosphorus fertilizer. With so many cattle in the area, bone meal probably would be the cheapest source of phosphorus to use in experiments and demonstrations.

5. When 82 per cent of the soils test high in potassium and 18 per cent test medium, it does not appear feasible to even consider the use of any potassium fertilizers in experiments or demonstrations in the near future.

Soils at Amibara

The productivity potential of 25 soil samples from five pits at the Amibara site are summarized in Table III. 6. Rooting depths vary from 80 to 200 cm. and appear to be ecologically satisfactory for good crop yields. Organic matter tests are from low to high and average slightly less than medium. Soil textures vary from loam to clay loam; acidity tests range from weakly alkaline to alkaline; available phosphorus is high; and conductivity tests are from

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[3]H.F. Murphy, *Fertility and Other Data on Some Ethiopian Soils*, Experiment Station Bulletin No. 4 (Dire Dawa: Imperial Ethiopian College of Agriculture and Mechanical Arts, February, 1963), p. 40.

TABLE II.6 PRODUCTIVITY POTENTIAL OF SOILS IN AMIBARA SETTLEMENT AREA TO THE ROOTING DEPTH INDICATED
(Average of 25 soil samples from five soil pits.)

Soil Profile No.	Rooting Depth	Organic Matter[a]	Soil Texture	Soil Acidity[b]	Available Phosphorus[c]	Salt Content (conductivity)[d]	Vegetation or Crop
	cm.						
I	200	low to medium	loam to clay loam	weakly alkaline	high	high to excessive	cotton
II	160	low to medium	loam to clay loam	weakly alkaline	high	excessive	cotton
III	190	low to medium	sandy clay loam	alkaline	high	medium to excessive	cotton
IV	170	low to high	loam to clay loam	weakly alkaline	high	excessive	cotton
V	80	medium	sandy loam to silt	weakly alkaline	high	high to excessive	cotton

[a]Soil organic matter ratings: high, above 2.0%; medium, 1.0-2.0%; low, less than 1%.

[b]Soil acidity (pH) ratings: very strongly acid, 4.0-5.0; strongly acid, 5.0-5.5; moderately acid, 5.5-6.0; slightly acid, 6.0-6.7; neutral, 6.7-7.2; weakly alkaline, 7.2-8.0; alkaline, 8.0-9.0; strongly alkaline, 9.0-10.0; excessively alkaline, 10.0-11.0.

[c]Available phosphorus (mg. of P_2O_5 per 100 g. of soil) ratings: high, above 2.0; medium, 0.4-2.0; low, below 0.4.

[d]Salt content (conductivity $1x10^{-3}$ reciprocal mhos per cm.) ratings: excessive, above 1.5; high, 0.8-1.5; medium, 0.2-0.8; and low, below 0.2.

medium to excessive. All test results apparently are normal for the production of most crops except for soluble salts which are dangerously high for salt-sensitive crops such as beans and most clovers. Salt-tolerant crops should be grown, and these include cotton and lucerne (alfalfa). Maize (corn) is grown on these soils, but salt injury may prevent maximum crop yields during some years when irrigation water is not applied in adequate amounts to keep the salt concentration in the soil at a low level. (Figures 2.6 and 2.7.)

Soils at Setit-Humera

The productivity potential for 84 soils from 13 soil pits spaced from 10 to 110 kilometers south of the town of Humera are portrayed in Table II.7.

Rooting depth is satisfactory, varying from 150 to 200 cm. The amount of soil organic matter is in general medium, but is higher near Humera. All soil textures are clay; almost all soil reactions are alkaline; available phosphorus tests are mostly medium to low, with an occasional horizon testing high; and the salt content ranges from medium to high at random depths at each soil pit tested.

Six of the surface soils at Setit-Humera (0-15 cm. depth) tested medium in phosphorus and seven tested low. These tests indicate that probably inadequate phosphorus is the first limit on plant growth in Setit-Humera. More soil tests and field experiments are needed to confirm this statement before phosphorus fertilizer is recommended to the farmers. A medium test for organic matter combined with the hot climate and a consequent rapid release of nitrogen, does not indicate that nitrogen fertilizer would give much crop response. (Figures 2.8 and 2.9.)

Figure 2.6 Amibara Plains (Middle Awash Settlement, Ethiopia): Deep clay Soils on the Amibara Plains consist of alluvium from the Awash River. The variation from deep clay to deep silt and clay loam is illustrated by comparing the deep clay shown in this figure with the deep silt and clay loam shown in Figure 2.7. (AFR-156)

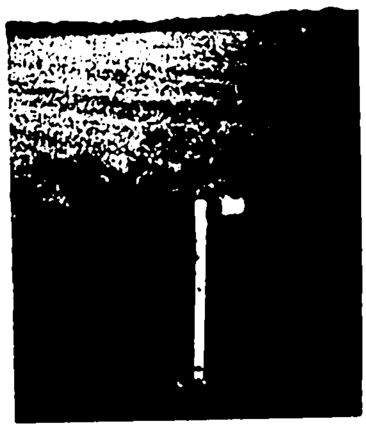

Figure 2.7 Amibara Plains (Middle Awash Settlement, Ethiopia): Deep silt and clay loam This area receives 350 to 450 mm. rainfall annually but flood waters from the Awash River are used by pump irrigation for a single cropping season. .-157)

TABLE II.7 PRODUCTIVITY POTENTIAL OF SOILS IN SETIT-HUMERA TO THE ROOTING DEPTH INDICATED (Average of 84 samples from 13 pits.)

Location of Soil Profiles	Rooting Depth	Organic Matter[a]	Soil Texture	Soil Acidity[b]	Available Phosphorus[c]	Salt Content (conductivity)[d]	Vegetation or Crop
Km. South of Humera	cm.						
10	150	medium to high	clay	alkaline	medium to high	not determined	sesame
20	150	medium to high	clay	alkaline	low	not determined	grain sorghum
30	200	medium	clay	alkaline	medium	not determined	cotton
40	200	medium to low	clay	alkaline	low to medium	medium to high	cotton
50	150	medium	clay	weakly alkaline to alkaline	medium	medium to high	grain sorghum
60	180	medium	clay	weakly alkaline to alkaline	medium	medium to high	sesame
70	150	medium	clay	weakly alkaline to alkaline	low	medium to high	grain sorghum
80	200	medium to low	clay	alkaline	low to medium	medium to high	sesame
90	150	medium to low	clay	weakly alkaline to alkaline	low	medium to high	tall trees and tall grasses
100	180	medium to low	clay	neutral to alkaline	low	medium to high	short trees and short grasses
110	150	medium	clay	neutral to alkaline	low to medium	medium to high	short trees and tall grasses

[a]Soil organic matter ratings: high, above 2.0%; medium, 1.0-2.0%; low, less than 1%.

[b]Soil acidity (pH) ratings: very strongly acid, 4.0-5.0; strongly acid, 5.0-5.5; moderately acid, 5.5-6.0; slightly acid, 6.0-6.7; neutral, 6.7-7.2; weakly alkaline, 7.2-8.0; alkaline, 8.0-9.0; strongly alkaline, 9.0-10.0; excessively alkaline, 10.0-11.0.

[c]Available phosphorus (mg. of P_2O_5 per 100 g. of soil) ratings: high, above 2.0; medium, 0.4-2.0; low, below 0.4.

[d]Salt content (conductivity $1x10^{-3}$ reciprocal mhos per cm.) ratings: excessive, above 1.5; high, 0.8-1.5; medium, 0.2-0.8; and low, below 0.2.

Figure 2.8 Setit-Humera (Ethiopia): Soil pit 10 kilometers south of Humera Soils of the Setit-Humera area are remarkably uniform in nearly all characteristics to a depth of at least 2 meters; the crop is sesame. Annual rainfall averages 500-700 mm. The soil is a Vertisol clay which cracks as it dries and has self-mulching properties as water is absorbed. (AFR-6)

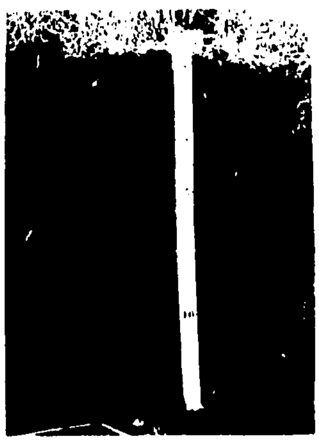

Figure 2.9 Setit-Humera (Ethiopia): Soil pit 110 kilometers south of Humera Sesame crop among much weed growth with a satisfactory rooting depth of 150 to 200 cm. Yields are severely affected by weed competition and most farmers complain of declining yields after the second or third season. Self-mulching soils such as these require minimum tillage for good tilth but good weed control must be incorporated into these cultivation practices. (AFR-536)

Case Studies of Hand-powered Agriculture

Three examples of hand-powered farm economies have been selected for description. The Agnale Village in southwestern Ethiopia on the north bank of the Baro River, was one of the five study sites. Also, fairly comprehensive information was made available of the systems in Upper Ghana and northern Nigeria. The description of each system is given in detail because the hand-labor economy is complex and the interrelationships must be carefully considered in the light of mechanization possibilities. This complexity is due to the fact that traditionally each unit must produce sufficient to meet its own needs, and in such a subsistence economy it is necessary to produce a wide variety of agricultural commodities to insure against risks of failures.

Agnale Village, Ethiopia

The form of agriculture practiced in this area of southwestern Ethiopia is the least sophisticated of all the areas studied. The site was chosen for the express purpose of providing a sharp contrast with the other sources of information on mechanization.

Agnale is situated approximately 50 kilometers west of Gambela close to the northern bank of the Baro River in the Province of Illubabor. The village is about eight kilometers across country and some 15 kilometers down-river from Pokwo where the American Mission Station is situated. The only means of communication for the local people is by the extremely rough track into Gambela, with all goods head carried. Gambela served the area as a river port for trade with the Sudan until this market closed. Now contact with potential markets is by air or by road through very rugged country.

The entire area is fertile, watered by the river which floods during the rainy season, June through October. Crops are adequate except for a short "hunger time" around the middle of the rainy season (May-September).

The Village and the People

The village, pleasantly shaded by tall trees, is situated close to the river and above flood-water levels. There are about 20 families although no census has been taken in the Gambela Awraja.[4] The compound area is surrounded by a thicket hedge; each family lives in one or more grass-walled and thatched circular houses.

Village elders reported a total number of 48 actively working men and boys who cultivate the fields on both sides of the river. (All boys over the

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[4] Imperial Ethiopian Government, *Report on a Survey of Illubabor Province* National Sample Survey Report No. 11 (mimeographed) (Addis Ababa: Central Statistical Office, June, 1968), p. 4.

age of 12 work in the fields. Women and young children do little work except planting and harvesting.) According to the census estimates made in other parts of the province, an active population of 48 suggests a total population in the region of 142 to 150.

The people are Anuaks, a Nilotic people, and today most are Christian. Close contacts have been maintained between these Anuaks and workers from Pokwo since the mission station was established some 15 years ago. (Figure 2.10.)

Figure 2.10 Agnale Village (Ethiopia): Village group shelling maize
Anuak village chief (center) in conversation with the Assistant Research officer (wearing cap). Maize ears are being shelled to estimate the yield for this crop. Maize stalks are chopped in field and laid down. Usually women and children gather the ears and shell the grain. (AFR-91)

The Land and the Farm

The people have been settled in the area for several generations. No legal titles to the land exist other than traditional occupancy. The area is intensively cultivated along the high banks of the river but the swampy hinterland, which falls to a lower elevation, is left uncropped.

Boys usually request a field to cultivate and all men continue in cultivation until they become too feeble to work. Plot sizes range from 0.6 to 1.0 hectares for maize (corn) and from 0.6 to 0.8 hectares for sorghum. There is no obvious division between fields and those worked by members of one family may be widely separated. Land is abundant and any request for a field is automatically granted after token consideration by the chiefs and elders.

On the basis of the estimated plot sizes and the 48 active field workers, the approximate size of the area under cultivation may be estimated as follows, assuming that each worker can cultivate only one field (1.5-1.6 hectares) each season.

	November-December planting:		
	48 plots of maize,	0.8 ha./plot	= 38.4 ha.
	48 plots of sorghum,	0.7 ha./plot	= 33.6 ha.
Total	48 fields	1.5 ha./field	72.0 ha.
	April-May Planting:		
	48 plots of maize,	0.8 ha./plot	= 38.4 ha.
	48 plots of fallow,	0.7 ha./plot	= 33.6 ha.
Total	48 fields	1.6 ha./field	72.0 ha.

Thus, the community at its present size is probably farming 72 ha. of good quality land, slightly less than half lying fallow during April-August.

Crops and Cultivation Practices

1) Maize (corn)

The main crop is maize, two crops being grown annually, planted in November and April. The local variety is open-pollinated with a growing season of 100 to 110 days. The maize is harvested when almost mature, *i.e.*, when dented and fairly hard. Maize forms the staple diet and the cultivation practices are as follows:

a) Precultivation The fields are prepared during the dry season prior to planting by clearing the old stalks and burning them. New fields may be cleared of grass during this time. Immediately after the rainy season when the waters have sufficiently receded, the soil is roughly broken by using their only agricultural tool,[5] the challa, a short wooden handled hoe (Figure 2.11) in one hand and lifting weeds and roots with the other. No attempt is made to turn over soil.

b) Planting The two planting seasons are in November and April. April is almost into the rainy season when only maize is grown. The men use the challa to dig holes in two rows at a time in a zig-zag pattern, breaking up the soil around each hole. The women-folk follow, dropping five or six kernels in each hole and covering the hole with a foot movement.

c) Weeding Maize ideally is weeded three times in the wet period and twice in the dry time. Weeding in fact often is inadequate due to lack of time and labor at peak seasons, although without proper weed control crops are poor.

[5]The *challa* is the only cultivating tool although a hooked branch, the *digano*, is used for pulling up long grass and weeds; there are also a number of hunting, building and blacksmith's tools used by villagers.

Figure 2.11 Kier Village (near Agnale, Ethiopia): The Challa
The *challa* is the principal agricultural tool of the region. It serves for tilling the soil, weeding, and digging out maize roots at harvest time. A villager demonstrates the art of preparing the soil prior to planting. At Kier (2 kilometers downriver from Pokwo/Agnale) the agricultural missionary has taught the villagers the value of leaving old stubble and weeds on the surface as a form of mulch to depress moisture evaporation. (AFR-64)

d) Harvesting The harvest periods are in July-August and February-March. Maize stalks are dug out with the *challa* and laid in rows. At the end of each day harvested maize ears are shucked by hand and carried in baskets, using canoes to cross the river, to the village where the ears are dried, or shelled, in the sun. The best ears are kept for seed.

e) Storage Woven branch and grass cribs, covered with thatched roofs, are used for storage of both maize and sorghum.

2) Sorghum

The people prefer sorghum to maize for taste and ease of preparation for cooking. However, harvesting takes much longer and only one crop is grown annually. The sorghum variety has a growing season of three months; thus it is possible, theoretically, to grow three crops in the year. However, the following discussion will demonstrate that this is not practicable because present cultivation practices make heavy demands for labor. Cultivation practices are as follows:

a) Precultivation The ground is cleared at the beginning of the dry season in November, and the land lightly broken in a manner similar to the preparation for maize.

b) Planting Before planting the seed is soaked. Planting is performed by the men working with *challas*; 10 or 12 seeds are dropped into a hole with a little water.

c) Weeding Sorghum weeding is slow and tedious work and there is only time for one weeding usually during February and March.

d) Harvesting During the period of maturation the crop has to be protected from birds by the boys and men. When ready, in April, sorghum stalks are dug up and piled. The heads are cut off and dried in the sun by the womenfolk.

3) Other Crops

Certain other crops are grown in small quantities, and give some variety to the diet. But, since the two main crops take up most of the available labor, there is little time to tend these other crops.

a) Beans About a hectare of beans is planted in November for harvest in January. Also, some beans may be planted among the maize plants.

b) Pumpkins The seeds are planted along field edges and in shady places in April-May as the rains begin. They have reached maturity by the time of maize harvest in July-August.

Calendar of Operations

The approximate time for the cropping sequence is recorded in Table II.8.

TABLE II.8 AGNALE VILLAGE: CALENDAR OF OPERATIONS

CROP	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.
									Rain (900 - 1000 mm.)			
Maize	plant	weed		harvest	clear	plant		weed		harvest		clear
Sorghum		clear	plant	weed		harvest	mature					
Beans	plant		harvest									
Pumpkin						plant			harvest			

TABLE II.9 AGNALE VILLAGE: ESTIMATED DISTRIBUTION OF LABOR REQUIREMENTS (MAN-DAYS) THROUGH CROP CALENDAR

MAIN CROP	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.
Maize	3(±1)	17(±3)		3½(±½)	17(±3)	3(±1)	25½(±4½)		3½(±½)			17(±3)
Sorghum		17(±3)	19½(±8½)	22(±8)	5(±1)							
Total (min.)	2	29		31		6	21		3			14
(avg.)	3	53½		42½		8	25½		3½			17
(max.)	4	68		54		10	30		4			20
Total available (365)	30	62		59		30	61		62		30	31
Additional crops		beans planted		beans harvested		pumpkins planted			pumpkins harvested			

Labor Distribution

Crop labor requirements, based on each man's cultivating his own fields without assistance are shown for each crop in Table II.9. These data show the amount of work that each active man must provide annually; the sum of labo requirements shown in Table II.9 identifies the periods when labor requirement are critical: in December and January. December through March are very busy months, weeding for both maize and sorghum.

Other Inputs

The only other input into this cropping pattern is the seed saved by each family from the previous season. Seed rates can be little better than a very rough estimate. (1) Maize seed: Each family retains approximately 40 kg. of good quality seed on cobs. A 50 percent germination rate would suggest about 20 kg./ha. of viable seed and therefore, an estimated 80 kilograms per annum are retained. (2) Sorghum seed: About 10 kg./ha. of viable seed is planted and produces three to four plants from ten planted seeds per hole for an estimated 25 kg. of seed per annum.

Yields of Major Crops

Estimates were made on a random sample basis by the Team for maize at 25 quintals per hectare. Allowing 10 percent for moisture[6] this reduces the yield to 22.5 q./ha. However, damage by birds and other pests probably will bring the yield closer to 20 q./ha. for the rainy season harvest in July-August and somewhat less, say 15 quintals per hectare, during the dry season harvest in February. As a rough estimate of yields for sorghum, 18 q./ha. appears reasonable; slightly higher yield than those for the Setit-Humera area can be expected because of the more fertile soil and higher rainfall.[7]

Estimated Annual Production

1) Maize

(Nov/Dec.)	38.4 ha. x 20 q./ha.	=	768.0 q.
(Apr/May)	38.4 ha. x 15 q./ha.	=	576.0 q.
			1344.0 q.

Assuming 40 percent loss in storage: maize for consumption equals 806 q. Assuming 10 kilos per person (adult) per week: 806 q. supply is adequate for 155 adults for one year. Thus 806 q. of maize is probably adequate for the total village population (142-150) not allowing for any variety of diet nor any reserve for seed, gifts, or emergencies.

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[6] Carl F. Miller, James D. Sarton, James L. Mackin, Peter O. Strom, *Systems Analysis Methods for Ethiopian Agriculture* Final Report, SRI Project 6350-202, AID Contract 6632-72 (multilithed)(Menlo Park, California: Stanford Research Institute, April, 1968), p. 92.

[7] *Ibid.*

2) Sorghum

(Nov/Dec.) 33.6 ha. x 18 q./ha. = 604.8 q.

Assuming 50 percent loss in storage: sorghum for consumption equals 302 q. Assuming 10 kilos per person (adult) per week: 302 q. is adequate for 58 adults for one year.

The final estimated quantity of grain production is adequate for 213 adults for one year, enough for the estimated population with a little to spare.

Value of Production

This system of agriculture allows no marketable surplus. Any surplus is reserved for guests, feasting and beer-making. Imputed values must be based on local market prices. Twenty kilos of grain, either maize or sorghum, can bring $0.80 at harvest, and $2.00 in periods of scarcity.

The economic balance of this system insures adequate production with a reasonable distribution of leisure throughout most of the year. Labor requirements during January-March render additional cropping impossible during the dry season, and any suggestion of growing additional crops of sorghum is unlikely to be well received since the system already produces adequate for the needs of the villagers. No market exists for surplus crops. Crop improvements and diversification could develop a more equitable distribution of labor demand. Proposals to introduce higher yielding varieties must also include consideration for coping with surpluses and increases in labor requirements at peak periods. It is at this point that mechanization becomes a realistic possibility if the economy can provide instructional facilities, an appropriate market, infrastructure, and an economic means of meeting higher operating costs.

Zuarungu District, Upper Ghana[8]

The small town of Zuarungu and the surrounding area comprise one of the three political sub-districts of North Mamprusi. Zuarungu district is heavily populated and shortages of cultivated food occur frequently.

Until the end of World War II the area was isolated at 800 km. from the coast, 560 km. from the nearest rail head and with inadequate roads. Since then a reasonably good all-weather road has been constructed from the south.

Natural vegetation is tree savannah. All the land not under cultivation has a covering of grasses which are usually burned in the dry season. The country gently undulates, with outcrops of granite rocks. Soils are grayish-brown and contain a high proportion of sand and gravel. Near the rocky

[8]Material for the substance of this section is drawn from *Extracts from Bulletin by Department of Agriculture in Northern Ghana about 1937* (mimeographed) (Government of the Gold Coast, reproduced by the National Investment Bank, Accra, Ghana, March, 1968).

outcrops, the soil is extremely stony. In valleys, soils are deeper, fertile, and very wet in the rainy season. Stones are frequently used to form contour terraces, but serious sheet erosion still occurs in the rainy season, and is aggravated by the burning of ground cover.

The area has a hand-labor agricultural economy. Since World War II, Bolgatanga has developed as a commercial center and local enterprises have been established: gravel extraction, meat packing, slaughter house, tomato packing, and basket making.

The pattern of agriculture is fixed due to the density of the population, although some farmers at the fringes of the area also have farms in the savannah which has a system of shifting cultivation. No villages exist; each family lives in a small isolated compound.

<u>The Compound and the People</u>

The family homestead (Figure 2.12)

> . . . resembles a miniature fort and in the past there is little doubt that it served as such; it is roughly elliptical in shape and consists of a number of round mud houses opening inwards; and the whole is enclosed by a high mud wall. Roofs are made either flat, of beaten mud, or conical, and thatched. A single narrow doorway, which can be heavily barricaded, gives entrance to the compound: the space inside is divided into compartments by low walls. Livestock are kept in an open compartment near the entrance. The land lying between compounds is farmed intensively and manuring forms a definite part of the farming system.[9]

The people largely follow animistic forms of religion. Each compound is home to an extended family consisting of a senior man, with his wives, his sons with their wives and children. Each wife with her children has a separate house within the compound and the members of the senior generation live in a separated area. Boys big enough to hoe are considered to be men; women and children only help to plant and harvest. Compounds average 3.2 men who support a total of 12 people (excluding babes in arms).

<u>The Land and the Farm</u>

Customs of land tenure are intimately bound up with the religion of the people. Each district is administered by a chief who exercises authority[10] over the people. The *tindana*[11] has final say regarding new residents, since

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[9] *Ibid.*, p. 6.

[10] It should be noted that this description was written in 1937. Gradually the authority of the chiefs is declining with the increasing power of the elected government and local administration of the regions.

[11] Local *shaman* (medicine-man).

tradition has established him as mediator between the people and the "spirit of the land". Seasonal dues have to be given voluntarily to the spirits by way of the *tindana;* in this area, without rents and cash income, these dues take the form of harvested crops.

The land is farmed in three functional divisions: the compound farm, located by the homestead; the intermediate farm, located between compounds; and the bush farm, extensively cultivated savannah.

The average farm sizes are:

Compound farm	1.98 ha.	(61%)
Intermediate farm	0.55 ha.	(17%)
Bush farm	0.70 ha.	(22%)
TOTAL	3.23 ha.	(100%)

Thus: 1 man farms about 1 hectare and supports 3.7 persons.

Figure 2.12 Zuarungu District (Ghana): Family homestead compound
The family compound, resembling a miniature fort in baked mud, is built by neighbors and the family together whenever a new family comes to the area, or a member of the family wishes to establish a new compound. Womenfolk finish the compound floors, grading them to facilitate drainage. The tall narrow cylinder covered with thatch (approximate center) is the granary. (AFR-268)

Mixed cropping is the general practice with all crops except root crops and tobacco. Proximity to the compound and fertility of the soil are the main determinants of crops planted. Staple crops are grown in compound farms which are manured, and the less fertile intermediate farms. Bush farms may be 2.4 to 3.2 kilometers away from the compound and receive only a single weeding.

Crops and Cultivation Practices

A wide range of crops are grown in the area. The following is a list of those more common:[12]

Early millet	Rice	Yams	*Neri*
Late millet	Groundnuts	Sweet potatoes	Calabash
Guinea corn	Bambarra beans	Coleus potatoes	Pumpkin
Maize	Geocarpa beans	Hibiscus (long)	Bungu
Cassava	Cowpeas	Soup plant	Sesame
Okra			

Crops and cultivation practices fall roughly within the functional divisions as follows:

1. The compound farms are manured with 4.48 to 11.2 metric tons per hectare which includes nightsoil as well as animal manure. The main crops generally mixed together, are early millet, late millet, cowpeas and *neri*. Minor crops, planted in empty places, include maize, hibiscus (long), *nangina* tobacco (near a wall), groundnuts (on sandy soil), rice (in patches), sweet potatoes, and bambarra (on gravel). Pumpkins, sesame and cassava sometimes are intercropped around the compound.

2. The intermediate farms produce the same crops with the omission of early millet and the addition of groundnuts. Cultivation begins later in these farms.

3. Bush farms produce guinea corn and cowpeas alternated with guinea corn and late millet. When yields decline the land is left fallow.

Early millet is harvested first, starting in June. The heads are cut at the neck by the men using short knives; the women carry the crop in baskets, to be dried in the compound. Maize is harvested similarly toward the end of July followed by guinea corn. The main harvest starts in mid-September with groundnuts followed by later guinea corn and late millet.

After harvesting, men and animals trample the stems of the cereal crops to the ground. Leaves are burned and charred stems are salvaged for fuel.

Cereal crops are stored unthreshed in tall conical baked-mud granaries built inside the compounds. Small seeds and soup ingredients are stored in calabash containers sealed with mud or dung to keep out weevils. Groundnuts are stored in large mud-sealed baskets.

Calendar of Operations

The calendar of cultivations is summarized in Table II.10.

[12] *Ibid.*, p. 50.

TABLE II.10 ZUARUNGU: CALENDAR OF OPERATIONS

Crop and Farm	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March
Mean monthly rainfall (mm.)	72.00	109.00	164.00	184.00	254.00	223.00	57.20	17.20	0.5	1.53	16.80 Annual	18.20 Total
											1107.	43
Compound												
Major Crops:												
Early millet	plant (2-3 days)	weed (twice)	harvest	earth up	late plants	final harvest		trash burning				
Guinea corn	plant (2-3 days)			weed			harvest					
Late millet	plant (2-3 days)		weed	thin and transplant				harvest				
Tobacco						transplant		weed			harvest	
Minor Crops:												
Maize, bersi, okra, *nangina* and others	plant			maize harvest								
Bambarra			plant									
Rice				plant	thin and transplant			harvest				
Intermediate Farm												
Guinea corn	plant	weed					harvest					
Late corn	plant	weed						harvest				
Groundnuts		plant	weed			harvest						
Tobacco					plant	Transplant to compound						

(Note: Bush Farm planting groundnuts, early millet, late millet and cowpeas occurs immediately after planting on the other farms; harvesting also follows other farms.)

Labor Distribution

Under the existing farming system, available labor is not used to capacity. The busiest time of the year is immediately after planting is finished, when weeding begins. This also is the time of food scarcity and the undernourished men cannot cultivate more than .04 hectares per day. Only at planting and harvesting are the men assisted by the women-folk.

Other Inputs

Seed is the only other important input. Each farmer keeps a little harvested grain for seed, but estimates are not available.

Yields of Major Crops

A summary of observations of indigenous crops 1932-1936 was published[13] in 1936 and, in 1967, provisional observations were made for unfertilized crops of improved guinea corn, late millet and rice. These data are presented in Table II.11.

The data indicate that manuring indigenous varieties results in considerable improvement in yields, and improved crop varieties can offer greater yields. However, estimates of yields for the earlier years were for mixed crops irrespective of the number of crops grown together, and 1967 estimates were for single crops. Single (sole) crop systems can improve agricultural technology by allowing specific treatments and operations, and individual observations of results.

TABLE II.11 ZUARUNGU: CROP YIELDS, 1932-1936; AND 1967

Crop	Manure Used	Average[a] 1932-1936	1967
		Kilograms/hectare	
Early millet	unmanured	302.4	n.a.[a]
	manured	565.6	n.a.
Late millet	unmanured	263.2	629
	manured	252.0	n.a.
Guinea corn	unmanured	364.0	582.4
	manured	543.0	n.a.
Groundnuts	unmanured	664.2	1120[b]
Rice	n.a.	n.a.	1025.0

[a] *Ibid.*, p. 25.

[b] Estimated.

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[13] *Ibid.*, pp. 24-25.

Livestock

There is a good potential market for meat, but livestock occupies a prestigious position in the economy. Cattle are viewed as a status symbol and a store of wealth rather than a good for general exchange. Cattle are occasionally eaten, used for religious sacrifice or in payment of bride-price. Livestock owned by an average family has been set out in Table II.12. Tending livestock is the responsibility of small boys, not old enough for heavier work.

TABLE II.12 ZUARUNGU: AVERAGE LIVESTOCK PER COMPOUND

Stock	Mean Number
Cattle	2
Donkeys	1
Sheep	3
Goats	11
Fowl	7

Despite inadequate attention local cattle (West African Shorthorn) are good looking animals with potential to produce good beef. Poultry thrives quite well in the area.

Estimated Annual Production

The total production for the major crops may be estimated assuming mean yields for a mixed crop.

Compound farm (manured): 1.98 hectares

x 565.6 kg./ha. = 1119.9 kg. (early millet)
x 252.0 kg./ha. = 499.0 kg. (late millet)
x 543.0 kg./ha = 1075.1 kg. (guinea corn)

Intermediate farm (unmanured): 0.55 hectares

x 263.2 kg./ha. = 144.8 kg. (late millet)
x 364.0 kg./ha. = 200.2 kg. (guinea corn)
x 664.2 kg./ha. = 365.2 kg. (groundnuts)

Bush farm (unmanured): 0.70 hectares

x 263.2 kg./ha = 184.24 kg. (late millet)
x 364.0 kg./ha. = 254.8 kg. (guinea corn)

Annual Total

Early millet	Late millet	Guinea corn	Groundnut
1119.9 kg.	820.0 kg.	1530.0 kg.	365.2 kg.

Assuming an average need of 10 kg. of grain per week per adult, the level of annual grain production is adequate for seven adults. Since the average number of persons per compound is twelve, grain production is barely adequate. It will be supplemented by groundnuts, root crops and other ground crops.

The present system of farming, little changed from the description given in 1937, *is now at a point in time when modern changes can begin.* There is

good access to a substantial market to the south, and the Ministry of Agriculture is assisting the farmers through the extension service with improved crop varieties and cultivation techniques. The established system has been adequate in good crop years but in bad years it produces insufficient for the peoples' needs. Starvation is avoided with wild foods. Since the labor requirements do not overtax the capabilities of the farming community, the area can be developed by raising crop yields and utilizing additional power to overcome deficiencies in timeliness of cultivation. Further, the potential for livestock production could be developed by a government-sponsored scheme incorporating local commercial enterprise. Such a scheme would have to overcome local indifference to animal husbandry and also take into account the relatively high population pressures. These pressures can be alleviated by bringing debilitating river-borne diseases under control which will free land from vector infestation.

Village Agriculture, Northern Nigeria[14]

The system of farming in the village economy of northern Nigeria represents another kind of hand-labor economy. The data has been taken from the village of Nasarawa. The people are Muslims and live in well-organized communities. Individual farming families produce for both themselves and the market. Many small farmers spend some of their time as wage-earners either on other farms or in nearby towns and villages. The economy of northern Nigeria is monetized and economically fairly sophisticated.

Ecologically, the area is classed as sub-Sudan savannah, with vegetation varying from close woodland to open scrub woodland.

The Compound and the People

Each family unit lives within the village community in a separated compound.

> The compound, *gida*, is a walled or fenced area entered via a single entrance hut and containing usually a forecourt and one or more interior courts. The interior court may be divided by a wall or fenced into portions, *sassa*, if the head of the compound has another adult male, relative or stranger, living within the compound. However, occupying the same compound and sharing the same entrance but does not connote membership of the same economic unit.
>
> The individual close family, *iyali*, may be understood as being a man, his wife or wives and his dependent children. The *iyali* often constitutes the economic unit. If two or more *iyali*

[14] Material for the substance of this section is drawn from C.J.N. Gibbs, *op. cit.*

cooperate in a common economic unit the resulting group is described as a *gandu*. There seems to be no hard and fast rule as to what will constitute an economic unit, one or more close family [groups].[15]

Nasarawa village has low-lying land which permits all-year cultivation. The people's ethnic origins are described as Hausa, Fulani, Gerawi and Sayarwa; villagers consider themselves to be Hausa, possibly with a headman claiming Fulani descent. The average number of persons per economic unit (*gandu*) is 5.95 with an average number of 3.57 labor units or 2.24 labor units for outside compound work; or 2.12 agricultural labor units. Thus, one labor unit supports 1.67 residents (2.86 if only active full-time farm workers are counted).[16]

The Land and the Farm

Land throughout Nigeria is regarded as common property. Each village head has authority in land affairs vested in him by the Emir. A farmer, however, can enjoy the rights of use so long as the land is used for the benefit of the community. Tenancy is by inheritance, allocation, or loan.

In certain low-lying areas, the water table remains high. The moist flood-plain areas, *ƒadama*, can be cultivated throughout the year. Cultivation of the higher land, *gona*, is strictly linked to the rainfall distribution (December and January are dry, while July, August and September are the wettest months). *Gona ƒadama* is land intermediate between these two types.

In the *ƒadama* the farmer can cultivate his farm throughout the year and crops are considerably more labor intensive. The average size of farms in Nasarawa village, where *ƒadama* occurs more frequently, is 2.36 ha. in contrast to the more extensive holdings of 4.61 ha. in the Nabayi village where *gona* occurs more frequently. Both villages have almost identical rainfall patterns, but the water retention property of the *ƒadama*, which only Nasarawa possesses, is much greater.

The average sizes of fields for the whole village are as follows:[17]

Average size of *gona* field	0.68 ha. (29%)
Average size of *gona ƒadama* field	1.32 ha. (56%)
Average size of *ƒadama* field	0.36 ha. (15%)
	2.36 ha. (100%)

[15] *Ibid.*, pp. 4-5.

[16] The labor unit gives an indication of the total family's physical potential for work but since women contribute nothing to work outside the compound, estimates of off-compound and farm labor need further modification. Labor units are estimated as follows:

Sex and Age of Individual		Labor Unit Equivalent
Male and female, 6 and under		0.00
Male and female, 7 to 14		0.50
Male	15 to 64	1.00
Female	15 to 64	0.75 (0.00 for agricultural labor)
Male and female, 65 and over		0.50

[17] Calculated on a proportional basis from the average data provided.

Fadama and *gona* fields are separate, and land fragmentation is considerable. The present pattern of farm structure does not favor innovations involving mechanization. However, with the exception of *fadama* and land perpetually attached to the compounds, there is a considerable degree of land mobility, due to the necessity of bush fallow practice. *This mobility could prove important in future attempts at consolidation.* In a comparable study Norman[18] noted that, in the village of Dan Mahawayi, the furthest field cultivated by a resident was 3.30 kilometers away from his compound.

Of Nasarawa farms, 17.87 percent of all of fields were cultivated as single blocks of the same crop; the remainder was cultivated in subdivided plots of single (sole) or mixed crops. Both single and mixed cropping is practiced, with 46.11 percent of all cultivated areas in single crops, 41.48 percent in double crops, 10.44 percent in three crops, and 1.97 percent in four crops.

The crop season is from April until November and family labor spent 88.4 percent of available work time on their own farm. Of available labor, 95.72 percent was male.

Crops and Cultivation Practices

Table II.13 presents a suggested approximation for the operations for major and some minor crops. Typical major crops are: guinea corn, millet, groundnuts, cowpeas, rice, cassava, sugar cane, omeri, and sweet potato. Typical minor crops are: okra, maize, benniseed, pepper, tobacco, tomato, and kenaf.

The date for man-days required per crop, presented in Table II.14, were obtained from estimates for Zaria Province which has a similar economy to Bauchi.

Calendar of Operations

The sequence of operations is presented in Table II.15, along with monthly average rainfall and temperature for the year. The average farm does not grow all these crops, but to hedge against risks of crop failure generally all the major crops are grown as well as selected minor crops.

Labor Distribution

The distribution of labor requirements for the cropping pattern is presented in Table II.16. The data suggest that the average worker contributes about 60 hours per month to cultivating the family farm, with an annual total

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[18] David W. Norman, *An Economic Study of Three Villages in Zaria Province I. Land and Labor Relationships* Miscellaneous Paper No. 19, (mimeographed) (Samaru, Nigeria: Ahmadu Bello University, Institute for Agricultural Research, RERU, 1967), p. 20.

TABLE II.13 NORTHERN NIGERIA: CROP OPERATIONS

Crop	Plant	Weed	Harvest
Guinea corn	April/May[a]	May/September	November/December
Millet	April/May	May/July	July/August
Groundnuts	May/June	July/August	October/November
Cowpeas	July	Aug. & Sept.[b]	October to December[c]
Cassava	May	July to Aug.	October to December
Rice	June/July	Aug./Sept.	October/November
Sugar cane	Oct. & Jan.	Apr. & July	Sept. & March
Onion	May	June & Aug.	August to October
Okra	April	May & June	June/July
Maize	April	May & June	July/August
Pepper	May	June & July	October/November
Tobacco	Aug./Sept.	Sept./Oct.	December/January

[a]Indicates one time falling within this period.

[b]Indicates two separate times.

[c]Indicates a continuous period.

TABLE II.14 NORTHERN NIGERIA: LABOR REQUIREMENTS FOR TYPICAL CROPS

Crop and Crop Mixture	Average Man-days Employed Per Hectare		
	Family Labor	Hired Labor	Total
Guinea corn	63.23	15.05	78.28
Groundnuts	88.95	44.48	133.43
Sugar cane	123.55	27.71	150.73
Cassava	74.13	29.65	103.78
Tobacco	44.48	32.12	76.60
Groundnuts/cowpeas	113.67	46.95	160.61
Onion/pepper	64.24	14.83	79.07
Guinea corn/millet	76.70	8.80	84.50
Guinea corn/groundnuts/ millet	94.00	16.21	110.21
Guinea corn/groundnuts	86.49	51.89	138.38
Groundnuts/maize	84.01	-	84.01

TABLE II.15 NORTHERN NIGERIA: CALENDAR OF OPERATIONS

	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec	Jan.	Feb.	Mar.	Total
Mean rainfall (mm.)[a]	36.0	75.1	147.1	253.7	342.2	194.1	34.9	1.0	0.0	0.0	0.5	0.54	1105.14
Mean temperature[a]													
Minimum, °C.	8.7	8.8	7.6	6.4	3.8	6.0	3.6	1.2	-1.9	-0.5	1.2	5.6	
Maximum, °C.	23.4	20.7	18.2	15.8	13.5	14.7	18.4	15.4	16.9	16.8	18.9	22.7	
Crop													
Guinea corn	plant		weed						harvest				
Millet	plant		weed	harvest									
Groundnuts		plant		weed			harvest						
Cowpeas				plant	weed			harvest					
Cassava		plant		weed	weed		harvest						
Rice			plant		weed		harvest						
Sugarcane 1	weed					harvest	plant						
2				weed						plant		harvest (year later)	
Onion		plant	weed		weed	harvest							
Okra	plant	weed	weed	harvest									
Maize	plant	weed	weed		harvest								
Pepper		plant	weed	weed			harvest						
Tobacco					plant		weed				harvest		

[a]Source: M.W. Walter, *Annual Summary of Observations* (Lagos: Metereological Service of Nigeria, 1961), *Passim.*

TABLE II.16 NORTHERN NIGERIA: ANNUAL FAMILY LABOR UTILIZATION, NASARAWA VILLAGE

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Work on family (*gandu*) farm	69.27	123.36	119.54	159.59	136.71	133.60	91.76	113.15	52.12	53.36	41.46	58.36	1152.25 (65.10%)
Work on other family farms	0.43	1.21	3.32	8.64	5.32	5.07	5.33	2.15	2.21	0.21	0.00	0.08	34.16 (1.93%)
Work in other occupations	75.89	41.83	51.02	45.44	43.52	40.61	57.31	53.82	45.29	50.83	44.71	33.29	583.54 (32.97%)
Monthly total per family, (*gandu*)	145.79	166.40	173.88	213.67	185.35	179.28	154.40	169.12	99.62	104.40	86.17	91.75	1769.95 (100%)

Source: Gibbs, *op. cit.*, Table 27.

of 168 days in farming (4.36 hours/farming man-day) and 51 days in other occupations. The average number of farming hours per day seems low, considerably less than 1000 hours per annum at farming. The man-hours per cultivated hectare demonstrates the intensity of farming on the fadama land:

	Average Annual Man-hours/cultivated ha.
fadama	[illegible]1.58
gona	498.89
average for all farm	586.44

<u>Other Inputs</u>

Seeds and fertilizer are the remaining input to be considered. Much is home grown and fertilizer is beginning to be used in northern Nigeria. Even a very modest application of 44.8 kg. per hectare at a price of $0.70 is likely to show economic results.

<u>Yields of Major Crops</u>

Yields of major crops in this area are set out in Table II.17.

TABLE II.17 NORTHERN NIGERIA: AVERAGE YIELDS PER HECTARE FOR NINE MAJOR CROPS, SINGLE (SOLE) AND MIXED CROPPING IN NASARAWA VILLAGE

Crop	1-crop	2-crop	3-crop	4-crop
	kilograms per hectare			
Guinea corn	663.0	603.7	425.6	305.8
Millet[a]	-	220.6	151.2	305.8
Groundnuts	369.6	189.3	52.6	206.1
Cowpeas[a]	-	104.2	35.8	50.4
Cassava[b]	2518.9	-	-	-
Rice[b]	490.6	-	-	-
Sugar cane[b]	3416.0	-	-	-
Onion[b]	3712.8	-	-	-
Sweet potato[b]	2539	-	-	-
Percentage of single (sole) or mixed crops in:	Percent			
gona fields	46.11	41.[illegible]	10.44	1.97
Single (sole) crop on fadama fields	100%	-	-	-

[a]Only grown in mixed crops

[b]Principal fadama crops which are single crops.

Livestock

All livestock in the economy of northern Nigeria is entirely in the hands of the Fulani people. Their way of life, a nomadic form of animal husbandry, is unrelated to the settled village life of the Hausa village. *In this Hausa-Fulani social system, there is a form of symbiosis between the two modes of living, but their separation creates special obstacles to the introduction of animal-powered technology.*

Estimated Annual Production

No indication is given of the distribution of the various crops in terms of relative areas. An infinite number of combinations of mixed crops and relative areas of each crop could be assumed; however, crop mixtures yielding the best gross output are given, and may be assumed to represent the optimal choice of efficient farmers. These estimates are set out in Table II.18 and, since the economy is integrated into a market system, may be valued at the current market prices.

TABLE II.18 NORTHERN NIGERIA: ESTIMATES OF TOTAL YIELDS FOR AVERAGE FARM AND AVERAGE MARKET PRICES (1967-68 season) IN KASARAWA VILLAGE

A. *Gona and gona fadama* fields (2.00 ha.)

Crop Mix	Proportion of Area	Area	Guinea Corn	Groundnut	Millet	Cowpeas
	percent	ha.	- - - - - - -	kilograms	- - - - - - -	- - -
1-crop	46.11	0.92	610.00	-	-	-
2-crop	41.48	0.83	501.10	-	183.10	-
3-crop	10.44	0.21	89.38	11.05	31.75	-
4-crop	1.97	0.04	12.23	8.24	12.23	2.02
Total	100.00	2.00	1212.71	19.29	227.08	2.02
Average market price ($/kg.)			0.049	0.082	0.048	0.07

B. *Fadama* fields (0.36 ha.)

Single Crop	Proportion[a] of Area	Area	Total Product	Average Market Price
	percent	ha.	kg.	$/kg.
Cassava	32	0.11	277.08	0.023
Rice	31	0.11	53.97	0.180
Sugar cane	19	0.07	239.12	0.018
Onion	11	0.04	148.51	0.039
Sweet potato	7	0.03	76.17	0.023
	100	0.36		

[a]Productions based on frequency of occurrence of these five principal *fadama* crops as single crops.

The village economy in northern Nigeria is viable and generally supports a hard-working population most of the time. During bad seasons there are food shortages, but generally the economy is somewhat more prosperous than the two cases already discussed. The working population is not over-taxed with labor demands from the farm and supplements the livelihood by earning wages on other farms or in non-farm occupations. The fact that this system is already fairly well monetized can be of considerable importance to future expansion of the economy.

The main deficiency of this type of economy is the size of the working unit. While yields can be improved by fertilizing and improved tillage practices, the small family operation places severe limitations on the type of machinery that can be operated.

Following study of three villages in the Zaria Province of northern Nigeria, 1966-67[19], Norman made the following observations on factors of production:

1) Capital

a) Gross farm income averaged $140.00 per family with all work done by hand and supplemented with income from non-farm sources. It probably costs about $140.00 yearly for food to support a family of six persons.

b) Many farmers remain in debt. Of an estimated 67 percent indebtedness among farmers in the far north of Nigeria the average indebtedness was $47.32, and only 18 percent of the indebtedness had been used for productive purposes. Rates of interest of 100 percent seemed to be common.

2) Land

a) The size of the family is the main determinant of size of holding, although the size of holding appears to be positively correlated with the degree of field fragmentation. Measures of land fertility and difficulty of acquiring more land were non-significant in statistical tests.

b) Upland fields (*gona*) support crops only during the rainy seasons; these crops are usually low-value crops (*e.g.*, groundnuts, millet and guinea corn). Lowland (*fadama*) fields support crops throughout the year; the crops are high-value and labor-intensive ones such as sugar cane and maize. Lowland is usually in high demand since it permits dry-season employment. However, in remotely located villages a high percentage of lowland is fallow or idle because of its relatively remote location away from markets for sugar cane.

c) In remote villages with plenty of land, the relatively low labor input leads to a high land to labor ratio.

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[19] David W. Norman, *Rural Economy Research Unit* (mimeographed) (Samaru: Ahmadu Bello University, Institute for Agricultural Research, [illegible], October, 1968), pp. 1-11.

3) Labor

a) The average number of man-hours employed varied from 398 to 917 man-hours/hectare for different villages, with the crop intensity almost the same. Mixed crops, incorporating up to 6-crop mixtures, account for 77.04 percent of cropped areas.

b) A working day is short (about five hours including travel time).

c) Off-farm employment is important especially during the dry season. Types and opportunities of off-farm jobs are determined chiefly by location.

d) Peak farming months for labor input are June and July. Off-farm employment showed a slight negative correlation with time devoted to the family farm, although 23 days were worked in June, compared with only 13 days in March.

e) The amount of land that can be managed during the peak labor months of June and July is the chief determinant of how much land a family can cultivate in any one year.

f) Most labor on family farms is that of family much adults. Hired labor, usually family farmers too, are most needed in June and July when they are busy with their own farms and when cash resources for paying hired labor are lowest. Statistical tests show no significant difference between seasonal distribution of family and hired labor on the family farm.

These three cases of hand-labor agricultural economies serve to illustrate the complexity of the productive process. The systems are not highly sophisticated in the commercial sense of integration between different groups of individuals: producers and consumers. They are complicated at the production stage because these groups of farming people have evolved a system over generations to meet all their basic needs. Moreover, it is a system which appears to have built-in hedges against risks of low yields or complete failures and the uncertainties of weather or other catastrophe. *The system maintains a balance in which the people have confidence of its capacity to provide at least sufficiently for survival.* The introduction of change may appear from within the system to imply an intolerably high level of uncertainty against which the means of insurance are unknown.

<u>Case Studies of Animal-powered Agriculture</u>

Two areas are selected to represent systems of animal-powered agriculture. Both are, in some degree, agricultural areas in transition. In the Chilalo Awraja (subprovince) of Ethiopia, where the Chilalo Agricultural Development Unit (CADU) of the Swedish International Development Agency has organized a technical assistance and cooperation program, oxen farming is well established and engine-powered agricultural technology has been fostered under the

Swedish program. The second area is in the vicinity of Bawku, at the small town of Garu in northeastern Ghana, close to Zuarungu. Additional observations on animal-powered agriculture have been taken from cases in Gambia and Tanzania.

Chilalo Awraja, Ethiopia

Chilalo Awraja is located on the eastern side of the upper Rift Valley about 150 kilometers south of Addis Ababa. The area covers one million hectares, a quarter of which is cultivated. Chilalo Mountain dominates the area, rising to a height of 4,500 meters; most crops are grown at elevations between 2,000 and 2,500 meters.

The area was selected for a special development program by mutual agreement between the Ethiopian and Swedish governments. Main objectives of the program are:

1. To conduct experiments on the improvement of production and marketing of agricultural products;
2. To disseminate new agricultural techniques;
3. To make studies concerned with the improvement of transportation, education, training, public health, commerce and industry.

Thus, already the area is under the influence of an ext[illegible]sive multidisciplinary development program, with the farming community aware of the thrust of new agricultural, social, economic and domestic techniques. Oxen are the predominant form of agricultural power, supplemented by 80 tractors, of which, the majority are operated by the CADU tractor hire service, and a few are privately owned.

Towns and the People

Asella is the principal town of Arussi Province which has a total population of 722,500. The rural population was estimated to be 690,600, of which the Chilalo Awraja has 52.3 percent (361,600).[20] Other main rural towns in the Awraja are: Sagure, Digelu, Gonde, Iteya, Hurutta and Dera.

A recent survey[21] divides the population of the Asella vicinity into 65 percent Orthodox Christian and 35 percent Muslim; of the ethnic groups, Galla are in the majority and Amhara the minority. These people live together in well organized towns; many farmers live in the towns and walk to their

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[20] Imperial Ethiopian Government, *Report on a Survey of Arussi Province* Report No. 2, (mimeographed) (Addis Ababa: Central Statistical Office, July 1966), pp. 4-7.

[21] CADU Extension and Education Department, *General Agricultural Survey of the Project Area* (mimeographed) (Addis Ababa: Swedish International Development Agency, July, 1968), p. 13.

fields. The average family in the sample was established as 6.3 persons.[22] Of the heads of farming families 5.1 percent have additional occupations: butchers, blacksmiths, carpenters, medicinemen, musicians, priests, traders, tailors, and weavers.

The Land and the Farm

Landowners comprise 68 percent of farmers in the sample in contrast to 32 percent tenant farmers.[23] Major ownership comes through purchases, grants or inheritance (*i.e.*, undisputed ownerships: 98 percent) (Figures 2.13 and 2.14), and the other principal form of ownership through appointment by the church authorities.

Four types of tenancy arrangements exist: 50-50 share-cropping in which oxen, implements and seeds are borrowed from the land owner and later repaid; 66 2/3 to tenant - 33 1/3 to landlord share-cropping in which the landowner provides half of the seeds; 75 to tenant - 25 to landlord share-cropping in which tenant provides all inputs except land; contract, in which the rent is stipulated in terms of produce and the landlord provides no other inputs.[24] Fragmentation exists in the form of separate farms. The degree of fragmentation is illustrated by the following data: average rented area, 3.5 hectares; average percentage of crop value paid in rents, 37; average number of fragments, 2.4.[25]

Farming is practiced by both owners and tenants. For both types of farmers the average farm size is estimated at 8.1 hectares of which 5.1 hectares is cropped land and the remainder is grassland; average area owned is 11 hectares with 5 cultivated.[26]

The area is at a high elevation and is fairly moist for most of the year. June through September is extremely wet and December is without rainfall. The land is fairly fertile and the area has excellent potential for modern agricultural technology. *Furthermore, rudiments of a monetary economy are established and the fairly sophisticated level of rural town life should facilitate the necessary specializations of modernization.*

Crops and Cultivation Practices

The types and percentages of crops and the average percentage in the area for each crop are presented in Table II.19. It is not unusual for a

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[22] *Ibid.*, p. 11.

[23] *Ibid.*, p. 15.

[24] *Ibid.*, p. 17.

[25] *Ibid.*, p. 18.

[26] Bo Bengtsson, *Cultivation Practices and the Weed, Pest and Disease Situation in Some Parts of the Chilalo Awraja* (mimeographed) (Addis Ababa: CADU, Swedish International Development Agency, March, 1968), p. 3.

Figure 2.13 Hurutta (Chilalo Awraja, Ethiopia): Small farmer's family and homestead The farmer and h's family stand in front of their home. The farmstead, protected from wandering animals by a brushwood fence, is located close to the small town of Hurutta. This farmer is the undisputed owner of about five hectares of land. To the right and behind the house is a small thatched grain crib in which harvested cereals are stored (Figure 2.15). (AFR-344)

Figure 2.14 Sagure (Chilalo Awraja, Ethiopia): Larger farmer, family and homestead The farmer (in suit), his wife (extreme right), his mother, sons and farm workers stand in front of farmer's house. Typical of a larger than average farmer, he is the undisputed owner of about 12 hectares of land. (AFR-345)

farmer to grow all these crops in any season. All crops are grown singly in separate plots.

TABLE II.19 CHILALO AWRAJA: RELATIVE PROPORTIONS OF CROPS GROWN, 1967

Crop	Percentage of Cultivated Land	Crop	Percentage of Cultivated Land
Wheat	31	Sorghum	1
Barley	41	Flax	8
Maize	3	Peas	7
Teff	2	Beans	6
		Other	1

Source: CADU, Extension and Education Department, *General Agricultural Survey of the Project Area*, p. 20.

Plowing begins about a week after the onset of the rains in March-April. However, land which has lain fallow is broken earlier, beginning in September or October. Three or four plowing operations take place on fallow land before soil burning (practiced generally only in the southern parts of the province) is begun in January-February. In order to break up difficult cloddy land and grass, turf plowing in several directions is practiced.

Land under cultivation in the previous season is plowed sometime between January-April. Land in flax and peas receives only one plowing but for other crops the second plowing takes place April-May, and in June, the third prepares the seed-bed. The fourth and last plowing is intended to cover the seed after broadcast planting but during this process much seed is buried too deeply for good germination. In the case of *teff*, seed is covered by animal trampling.[27]

Manures of dung, grass and ashes are applied to cropland, but most dung is used for fuel; the application follows the first plowing. In the area south of Asella, manure is added after soil burning, followed by a final plowing before planting.[28]

Some crop rotation is practiced. Most frequently, flax precedes and barley follows fallow. The following are the most general rotations:

1. barley -- fallow,
2. barley -- beans or peas -- flax -- fallow,
3. barley -- wheat -- beans or peas -- flax or fallow -- fallow.[29]

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[27] *Ibid.*, pp. 5-10.

[28] *Ibid.*, p. 10.

[29] *Ibid.*, p. 13.

Crop planting times are set out in Table II.20 along with approximate seed rates and prices. Seed rates of local farmers vary widely.

TABLE II.20 CHILALO AWRAJA: PLANTING TIME, APPROXIMATE SEED RATES, COSTS

Crop	Average Planting Time[a]	Approximate Seed Rate[b]	Approximate Costs[c]
		kg./ha.	dollars
Wheat	July	115	8.00
Barley	early-mid July	116	5.00
Teff	early-mid July	50[d]	14.00[d]
Maize (corn)	mid-late April	60[d]	4.80[d]
Sorghum	late March-late April	n.a.	4.80
Broad beans	late June-early July	99	4.80
Peas	mid July	131	4.80
Lentils	mid July	n.a.	n.a.
Flax	mid-late June	74	10.80

[a]Bengtsson, *op. cit.*, p. 23.

[b]Lars Leander, *A Case Study of Peasant Farming in the Digelu and Yeloma Area, Chilalo Awraja, Ethiopia* (mimeographed) (Addis Ababa: CADU, Planning and Evaluation Section, Swedish International Development Agency, January, 1969), p. 46.

[c]*Ibid.*, p. 92.

[d]Estimated from survey of 12 farmers by the Study. (The Agricultural Economist and the Assistant Research Officer gathered information in a small survey of 12 farmers in this area.)

Calendar of Operations

The details for the cultivation of crops are contained in Table II.21.

Labor Distribution

A suggested pattern of labor distribution for a farm of 3.1 hectares is given in Table II.22.[30] Labor requirements beyond that provided by the farmer and his wife are met by a hired worker earning about $40.00 a year plus room and board. Additional labor can be hired during the harvest period. The wage for day labor varies from $0.32 to 0.40 per day

[30]Estimated from data for a farm of 4.4 hectares in the Digelu area.

TABLE II. 21 CHILALO AWRAJA: CALENDAR OF OPERATIONS

Annual Rainfall (Kulumsa Farm)[a] 1967 Recorded rainfall (mm.)	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	1.3	0.5	85.3	45.5	87.5	69.7	172.9	149.8	140.3	66.8	65.3	0.0	884.9
		(small rains)				(rainy season)							
Mean temperature minimum	6.4	8.6	10.2	11.4	11.0	10.4	11.1	10.5	10.0	10.5	6.5	6.5	
maximum	21.4	24.1	24.3	23.3	22.7	22.4	19.4	18.6	19.1	20.5	19.5	19.6	
Crop													
Wheat	harvest		plow (3 times)				plant		weed			harvest	
Barley			plow (3 times)			plant			weed				
Teff			plow (3 times)			plant			weed				
Maize		plow (2-3 times) plant							weed				
Sorghum		plow (2-3 times) plant						weed				harvest	
Broad beans			plow (3 times)				plant		weed				
Peas			plow (1 time)				plant		weed				
Lentils			plow (3 times)				plant		weed				
Flax	harvest		plow (1 time)			plant			weed				
Fallow										break soil & burn soil			

[a]Chilalo Agricultural Development Unit, *Results of Trials and Observations of Field and Forage Crops at the Kulumsa Farm and in Asella* (mimeographed) (Addis Ababa: Swedish International Development Agency, June, 1968), p. 6.

TABLE II.22 CHILALO AWRAJA: ESTIMATED ANNUAL DISTRIBUTION OF LABOR REQUIREMENTS

Farm Worker	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	- - -	- - -	- - -	- - -	- - -	man-hours	- - -	- - -	- - -	- - -	- - -	- - -
Husband	142	[illegible]	56	30	25	65	70	44	64	38	60	115
Wife	44	15	4	0	0	4	6	5	20	0	0	32
Hired Worker	161	198	79	31	76	79	90	62	94	41	62	121
Total man-hours	347	339	239	61	101	148	166	111	178	79	132	268

Figure 2.15 Sagure (Chilalo Awraja, Ethiopia): Local grain cribs
These bins are on the 12 hectare farm at Sagure. The loose woven wattle and daub construction leaves the stored grain easily accessible to rodent and insect attack. In some cases farmers line the cribs with hard manure and mud from 2-5 cm. thick. Plaster has been experimented with to line the cribs to facilitate fumigation but rodents tear holes in the lining unless the crib is elevated and protected by antirodent climbing shields. (AFR-367)

Other Inputs

In addition to labor the main input is seed. Farmers generally use their own seeds but also make purchases on the local market and, increasingly, from CADU. The standard variety, Kenya I, sold at $10.40 per quintal is popular but other varieties have shown greater improvement than Kenya I in field trials: Azizia, 49 percent increase and Romany, 94 percent over Kenya I yields.[31]

The usual mode of transport is the donkey carrier, whether owned, loaned or occasionally hired at a charge of $0.16 per quintal. Sacks are an additional cost at $0.10 per quintal of grain. Until sold or used on the farm grain is stored in basket-like grain cribs (Figure 2.15).

In addition to these inputs into the local farming practice, the CADU development program is influencing basic cultivation practices. *A well-organized extension service disseminates the results of experimental work and assists the farmers in improving cultivation techniques.* Model farmers work closely with the extension agents.[32]

Yields of Major Crops

The average yield data shown in Table II.23 are based on random crop sampling; generally yields decline with increasing altitude.[33] The farming system is integrated into a market economy allowing market prices to be estimated for each crop. These are included in Table II.23.

TABLE II.23 CHILALO AWRAJA: ESTIMATED YIELDS, MARKET PRICE AND VALUES FOR MAJOR CROPS, JANUARY, 1969

Crop	Average Grain Yields (10% moisture)	Market Price	Average Value
	quintals/hectare	dollars/quintal	dollars/hectare
Wheat	11.6	8.20	95.12
Barley	16.0	4.80	76.80
Maize	31.1	4.00	124.40
Teff	12.1	12.00	145.20
Sorghum	12.8	4.00	51.20
Flax	4.5	8.00	36.00
Beans	16.1	4.40	70.84
Peas	10.9	5.60	61.04
Lentils	n.a.	12.00	n.a.

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[31] CADU, *Results of Trials and Observations of Field and Forage Crops at Kulumsa Farm and in Asella*, pp. 17-18.

[32] CADU, Memorandum: *Criteria for Selection of Model Farmers* (mimeographed) (Addis Ababa: Swedish International Development Agency, June, 1968).

[33] CADU, *Crop Sampling in the Chilalo Awraja, Arussi Province* (mimeographed) (Addis Ababa: Swedish International Development Agency, June, 1968).

Livestock

Each farm carries livestock, for which approximate numbers are recorded in Table II.24.

TABLE II.24 CHILALO AWRAJA: LIVESTOCK NUMBERS AND VALUES FOR AN AVERAGE FARM

Livestock	Average No.[a]	Approx. Unit Value	Total Value[b]
		dollars	dollars
Oxen	2	36.00	72.00
Lactating cows	2	30.00	60.00
Dry cows	2	20.00	40.00
Other cattle	4	12.00	48.00
Sheep	6	4.80	28.80
Goats	1	4.80	4.80
Horses	1	40.00	40.00
Donkeys	1	12.00	12.00
Mules	-[c]	-	-
Poultry	2	0.40	0.80
		TOTAL:	306.40

[a]CADU, Extension and Education Department, *General Agricultural Survey of the Project Area*, p. 25.

[b]Estimated from survey of 12 farmers.

[c]Less than one.

Many farmers pay for grazing rights on the lowlands where other herdsmen look after the stock during a maximum period of June through December. A typical charge per head per month is $0.20-0.40 for cattle and $0.16 for sheep and goats.

Estimated Annual Production

Estimated annual production of an average farm is calculated in Table II.25.

TABLE II.25 CHILALO AWRAJA: ESTIMATES OF TOTAL CROP PRODUCTION FOR AN AVERAGE FARM

Crop	Hectares	Total Production	Approx. Market Value
		quintals	dollars
Wheat	1.58	18.33	150.31
Barley	2.09	33.44	160.71
Maize	0.15	4.65	18.60
Teff	0.10	1.21	14.52
Sorghum	0.05	0.64	2.82
Flax	0.41	1.85	14.80
Peas	0.36	3.92	21.95
Beans	0.31	4.99	21.96
Other	0.05	-	-
	5.10		405.67

The area has a fairly well-established commercial economy which forms the basis for economic development. A significant amount of farm produce is marketed in the local towns and farmers operate in an economic system with wide fluctuations in the annual cycle of income and expenses. Income from crop sales is negligeable in June, October, November and December; builds up a little from January to May; and the bulk of income flows into the farm in September. Livestock sales are confined to January and May with a very small amount sold in October.[34]

Agriculture in the Chilalo Awraja is in a state of transition. Improvements are being introduced in the form of new tools, fertilizer and seed varieties. Fundamental change is taking place in expanding the use of tractor-power, through CADU hire facilities. Owners of larger farms (20 hectares and over) are willing to pay the relatively high charge of $4.80 per hour to have their land disk-plowed rather than continue with the tedium of conventional ox cultivation. Some farmers with over 40 hectares of land already own tractors and others are buying tractors on either an independent or cooperative basis; they recognize that for production of wheat and other cereals for the market, modern agricultural tillage equipment is superior if means can be found to buy or hire the right equipment.[35]

Christian Service Committee, Garu, Upper Ghana

The hand-labor economy in the Upper Region of Ghana already has been described in an example from the Zuarungu area. The system of farming at Garu, north-eastern Ghana is very similar to the Zuarungu area. The Christian Service Committee (CSC) is working with the local Kusasi farmers to renew an abandoned system of animal-powered agriculture.

Oxen training centers were established at Zuarungu in 1934 and in the Northern and Upper Regions of Ghana, in the districts of Bawku, Navrongo and Tamale in 1938. From Independence until 1966 farming with oxen was discouraged and the meat-packing station established in the area eliminated many animals. Now, the number of oxen is being increased with attempts to re-equip and retrain farmers in the forgotten techniques.

Cattle in the Local Economy

Traditionally, the Kusasi people are crop farmers. Any cattle are regarded as a store of wealth but the owners leave them to the care of the Fulani, nomadic cattle-herders, for a price of about $1.00 per animal per annum, and do not attend or use them as work animals. Table II.26 shows an estimation of the numbers of oxen farmers in the area for the period 1955-1968.

[34] Leander, *op.cit.*, p. 81.

[35] Bengtsson, *op.cit.*, p. 15.

TABLE II.26 NORTHERN AND UPPER GHANA: OXEN FARMERS 1955-1959 and 1968

Region and District	1955[a]	1956[a]	1957[a]	1958[a]	1959[a]	1968[b]
Upper Region						
Bawku	971	1,200	1,787	2,250	2,250	3,000
Bolgatanga	116	143	200	250	280	200
Lawra	16	17	7	9	11	-
Navrongo	438	494	572	596	640	500
Tumu	-	1	1	1	1	-
Wa	-	2	1	2	1	-
Northern Region						
Tamale	40	40	37	37	37	20
Wale Wale	104	95	223	259	532	450
Yendi	20	20	23	23	23	15
Total	1,705	2,012	2,851	3,427	3,775	4,185

[a]Source: Republic of Ghana, *Miscellaneous Information, 1960-1961* (mimeographed) (Accra: Ministry of Agriculture, 1962), p. 66.

[b]Estimates by N. Tenli, Deputy Chief Agricultural Officer, Tamale.

This area is heavily populated;[36] both humans and cattle are in competition for food producing land. The situation is aggravated by black fly (carrier of river blindness) in low-lying river areas, making them uninhabitable.

Since the change of government in 1966 there has been more encouragement for oxen farming. The principal crops which can be cultivated are: groundnuts, guinea corn, maize, millet and rice. The government is promoting the use of the Ransome ox plow; the Northern Region extension service reported 1,475 sold in 1967, and 40 Unibar multi-purpose toolbars brought into the area by local agents for trials and demonstrations.

It has been estimated on the basis of current crop values and the crop distribution that to justify owning a pair of oxen, a farmer should have between 4.05 and 6.07 hectares of crop land, 70 days of tillage work and 190 days per annum of carting work for each pair of animals. One estimate of crop distribution and workdays is given in Table II.27.

The entire area of the Northern and Upper Regions of Ghana is suitable for the development of mixed farming but good draft animals are unavailable and farmers lack credit to purchase them. *The experience of local farmers is that their animals are neither large nor strong enough to pull the ox equipment introduced into the area by the government.*

Function of the Christian Service Committee

The Christian Service Committee (CSC) has been responsible for developing a light ridging plow, fitted with a yoke, which one local ox can draw. The

[36]The following data are available from the 1960 General Census: Bolgatanga Administrative District (includes Bawku sub-district) Total Area: 2,175.6 square kilometers; Total Population: 336,857; Total Cattle: 72,467; Total Oxen farmers: 3,200; Total tractor farmers: 6.

TABLE II.27 NORTHERN GHANA: ESTIMATE OF FARM CROP DISTRIBUTION AND OXEN TEAM WORKDAYS

Crop	Area	Oxen team-days per hectare per annum	Total oxen team-days per annum
	hectares		
Groundnuts	0.809	19.77	16
Guinea	1.214	12.34	15
Maize	1.214	12.34	15
Millet (late)	1.214	12.34	15
Rice	0.809	9.90	8
Total	5.260		69

Source: S. Tenli, Regional Agricultural Officer, Tamale District, Personal Interview, April, 1968.

price of the plow carries a slight subsidy by the CSC[37] and is within the reach of most local farmers after one seasons' use. Many farmers make the implement pay for itself by taking on contract work with neighbors. Carting is another innovation. The new cart can be manufactured out of local material for $15.74 and is to be drawn by a pair of donkeys. Donkeys are plentiful, more easily managed, relatively cheaper than oxen and there are no cultural ties as with cattle (forming part of the bride-price). However, donkeys are not as strong as oxen.

The CSC is responsible for other innovations: an inexpensive grain silo which is vermin-proof; digging wells in an attempt to alleviate local water shortages; the development of compost manufacturing; carpentry demonstrations to improve the quality of domestic furniture; and demonstrations to improve local domestic sanitary conditions.

This is a pragmatic approach to local agricultural technology including the establishment of a small training school for short course instruction on practical problems and innovations, for illiterate farmers.

Relevant Aspects of Local Adaptive Research

This work of the CSC demonstrates three important principles as part of the process of agricultural mechanization:

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[37] The plow appears on the price list for 1968 at $37.48. The price breakdown was as follows:

Plow at cost	$ 36.29
Packing	2.47
Transport	2.20
Administration	0.25
Insurance	0.54
Total Cost	$ 41.75

1. Local problems must be studied separately and can be solved only partially by remote government sponsored programs. *Adaptive research must be carried out in the specific areas where new technology is to be applied.*

2. Animal-powered mechanization is an important teaching device for a population accustomed only to hand-powered tools, since *new principles of cultivation can be demonstrated and learned without the added complications of more sophisticated machinery.*

3. Local instruction courses become popular if designed to come to grips with local problems *in terms and methods which can be assimilated by local people.*

Additional Observations on Animal
Power: Gambia, Tanzania

<u>Gambia: Transition from Hand-powered to Animal-powered Agriculture</u>

In 1955 the government of Gambia established an Ox-plowing School, and in 1964 the name was changed to Mixed Farming Centre. By 1965 there were 24 such centers, and as of June, 1966, 320 trainees had enrolled. Each trainee is a young man from 15 to 35 years of age who takes his two oxen to one of the centers for a period of 8 1/2 months; receives no cash but does receive food for himself and feed for his oxen. On completion of the course each trainee is encouraged to buy a complete set of improved ox-drawn implements on liberal credit terms.

In 1964 a special evaluation study was made of ox-plowing in Gambia and the principal conclusions were:

> . . . most of extension staff who participated in the survey . . . will admit that oxenization is liked by the majority of the peasant farmers because they rightly come to realize that it is the most immediate answer to their mechanization objectives . . . such a phase which does also safeguard us from an unprepared embarkation on the delicate subject of mechanization [tractorization] of tropical soils.[38]

The more efficient farm power permits the farmer to increase his total production, *not by increasing yields per hectare, but by increasing the hectares per man.* For example, in Gambia a detailed study was made of ox-cultivation versus hand-hoe cultivation by a study team led by Peacock from the University of London. In the study the following groups were identified:

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[38] Ibrahim M. Drammeh, *Report on the 1964 Ox-plowing Survey in the McCarthy Island Division of The Gambia* (mimeographed) (Department of Agriculture, Government of The Gambia, January 29, 1965).

1. Farmers owning and using only hand-hoes.

2. Farmers owning only hand-hoes but using the ox-plowing and ox cultivation service supplied by neighboring farmers.

3. Untrained farmers owning and using ox-drawn equipment.

4. Trained farmers owning and using ox-drawn equipment.

The yield per hectare, total hectares, and total production of groundnuts and millets for farmers in Group 1 (hand cultivation only) were calculated on a relative base of 100 and the corresponding yields, hectares, and total production for Groups 2, 3 and 4 were averaged and compared as one group because all of them used ox-cultivation. These data are given in Table II.28.

TABLE II.28 GAMBIA: A COMPARISON OF THE RELATIVE PRODUCTIVITY OF GROWING GROUNDNUTS AND MILLETS[a] BY HAND CULTIVATION ONLY AND OX CULTIVATION

Productivity Factor	Hand Cultivation		Oxen Cultivation		
	Groundnuts	Millets[a]	Groundnuts	Millets	Average
Index of Yield	100	100	95	106	100
Index of Area	100	100	124	142	133
Index of Total Production	100	100	118	148	133

[a]The term millets includes guinea corn, pearl millet, and *digitaria exilis*, a minor millet.

Source: J.N. Peacock, *The Report of the Gambia Ox-ploughing Survey, 1966* (London: Wye University College Exploration Society, March, 1967), p. 7.

The results of the study suggest labor efficiency of the farmers using oxen-power was 31 percent greater and gross income 44 percent higher than comparable farmers using only hand-power. *Ox cultivation in Gambia permitted each farmer to obtain the same yield as other farmers who used only hand cultivation and also to increase his total production by 33 percent by cultivating 33 percent more land.* Fortunately, in most countries in Equatorial Africa there is adequate land for expansion, but only the best soils should be used (Figure 2.16 and 2.17).

Tanzania: Some Observations on Animal-power and Engine-power

During the past year the government of Tanzania has moved away from a policy of actively encouraging engine-powered mechanization to one of limited use of tractors. More attention is now being given to oxen cultivation, with recognition that tractors involve high production costs, a wide range of specialized supporting services, and skilled technicians. The cropping potentials and soil types were examined in many areas of Tanzania and, where potential crop output does justify tractors, the government does not encourage their use. However, tractors are advocated where the scale of operations is sufficiently

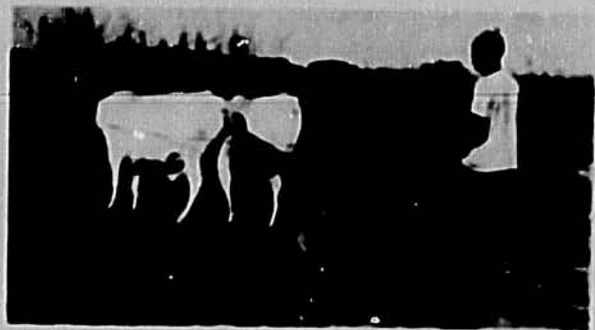

Figure 2.16 <u>Oxenization in Gambia: NIAE toolbar</u> All 24 Mixed Farming Centres in Gambia teach young hand-hoe farmers to become oxen-power farmers. A detailed study of oxenization in Gambia revealed that on the average the ox-powered farmer cultivates an area one-third larger and produces one-third more field crops than hand-hoe farmers, while yield remains unchanged. A further increase in agricultural productivity can be expected following the use of improved seeds, fertilizers, plant protection and improved harvesting and marketing practices. This picture shows a young farmer using the multi-purpose NIAE toolbar to which is attached a ridging body. (AFR-524)

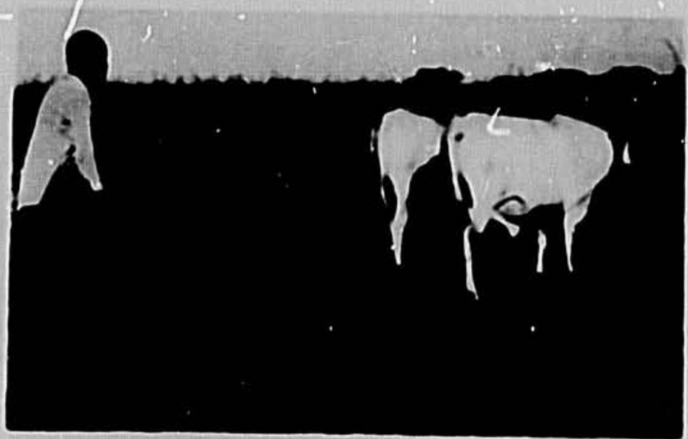

Figure 2.17 <u>Oxenization in Gambia: Emcot S-30 ridger</u> This picture shows a young farmer using a single purpose Emcot ridger made by Ransome. The ridging plow helps the farmer to overcome the tillage and land preparation bottleneck and also permits him to prepare and plant more land than he and his family can effectively weed. Additional weed control techniques are necessary to overcome this new limitation. (AFR-525)

large. (The capacity of a pair of oxen has been estimated for Tanzania as 4.86 hectares per annum.)

In Tanzania there are serious limitations to the use of oxen, enumerated as follows: (1) the presence of debilitating disease carriers (e.g. tsetse fly); (2) a high population pressure requiring most land to be kept in crops for human consumption; (3) local lack of experience in handling cattle; (4) farmers insufficiently skilled in oxen techniques; (5) ox equipment generally not very durable; (6) frequently, high mortality among oxen due to lack of care.

Encouragement in the use of ox-power through expanding research and testing has helped to adapt ox-drawn equipment to suit the particular soil conditions and farming systems in Tanzania. It is believed that a number of ox and farmer training centers should be established. Some cooperative unions and societies may be encouraged to hold stocks of standard ox implements so that they are available for local use. Field officers will be encouraged to receive instruction in ox-cultivation techniques.

These points illustrate Tanzania's new attitude toward oxen as an important source of farm power. However, Collinson[39] has pointed out in his farm management survey of the Maswa district that no significant benefit appeared to have accrued to farmers in introducing a new oxen cultivation practice into an already well-integrated hand technology. The importance of problem-solving at the local level is reiterated in this statement since the introduction of a new medium of power cannot be successful if merely *added* to a satisfactorily integrated system. New forms of power lead to changes in the system as existing constraints are overcome and new constraints become apparent.

A Note on Ox Training[40]

In the African system, two to three men are required to drive and guide pair of oxen in plowing or cultivating. One man leads the oxen, one holds the plow or cultivator, and sometimes a third prods or whips the oxen. In an effort to improve matters, consideration was given to the system used in the Far East, particularly in India, where a pair of oxen is used and controlled by one man with rope reins attached to a nose rope. The Indian method involves

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[39] M.P. Collinson, *Farm Management Survey No. 3: Luguru Ginnery Zone; Maswa District; Shinyanga Region, Tanganyika* (mimeographed) (Ukiriguru, Tanganyika: Western Region Research Center, 1964), p. 30.

[40] *Minutes of the Meeting of the East African Machinery Specialist Committee* (extracts from the minutes, Tengeru, Tanzania, January 9, 1963)), p. 1.

piercing a hole in the septum of the nose, passing a rope through, and tying it behind the horns; nylon rope has proved best. The beast is then left for three weeks for the wound to heal; the rope is turned carefully every day in the septum.

In the next stage, a long rope was tied to the nose rope behind the horns of each ox. One man for each ox was required, and he keeps behind the ox at all times. After one and two hours, it is possible to dispense with the two men and bring in the trainer with his assistant. After three or four hours work, the ends of the long ropes (reins) are joined together and one man takes over. Within a few days of training the pair of oxen can be hitched to an ox-cart. After a few weeks with an ox-cart they can be allowed to pull light implements, and in two or three months the oxen are ready for normal farm work.

The oxen must never be allowed to become excessively tired or discouraged during the training period. There could be difficulties from the supervisory point of view with piercing the nose and making sure the rope was turned daily during the first three weeks.[41] (Figures 2.18 and 2.19.)

Some General Conclusions on Oxen Power

Ox-cultivation techniques have certain advantages, particularly for the small farmer, over the use of tractors: (1) low running costs and no necessity for depreciation allowances since replacements are home-bred; (2) fairly easy management; (3) the multipurpose nature of the animal, providing manure, farm power and ultimately meat; (4) the comparatively small cash payments needed to operate a pair of oxen, almost negligible compared with operating a tractor; and (5) minimal foreign exchange requirements.

The disadvantages of oxen in comparison with tractor cultivation are: (1) the slowness of oxen which makes timeliness of cultivation a problem; (2) control of the animals is more difficult and can render cultivation less precise; (3) ox-plowing is difficult in breaking new land, heavy land, and weedy soil; (4) certain operations are impossible by oxen; (5) fitness of oxen is determined by the quality of feed available. Oxen must have suitable grazing land and cannot operate well if they are badly scoured at the beginning of the plowing season; (6) oxen farming is impossible in tsetse fly areas unless the animals are resistant to trypanosomiasis;[42] (7) there are certain cultural attitudes (discussed in relation to agriculture in northern Nigeria and the work of the CSC) which militate against mixed farming.

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[41] In the minutes of a meeting of the same body held two years later at Egerton College, Njoro, Kenya, the following statement is found (p. 2): "It was agreed that training of oxen in pairs to the Far Eastern (Indian) system was proving a great success but needed expanding in some areas."

[42] The geographical distribution of tsetse fly and livestock producing areas in Africa are shown in Figures 2.20 and 2.21.

Figure 2.18 Oxenization in Tanzania: The African method of ox driving
The most common African method of ox driving consists of at least two men, one with the implement and one with a whip and a loud voice. (AFR-127)

Figure 2.19 Oxenization in Gambia: The Asian method of ox driving
The Asian (Indian) method of ox driving is being introduced into Gambia because of the more superior control over the animals. It consists of a rope through the nose and one rein (line) for each ox. In this way one man can handle the oxen. The Mixed Farming Centres are using this Asian method with success. (AFR-526)

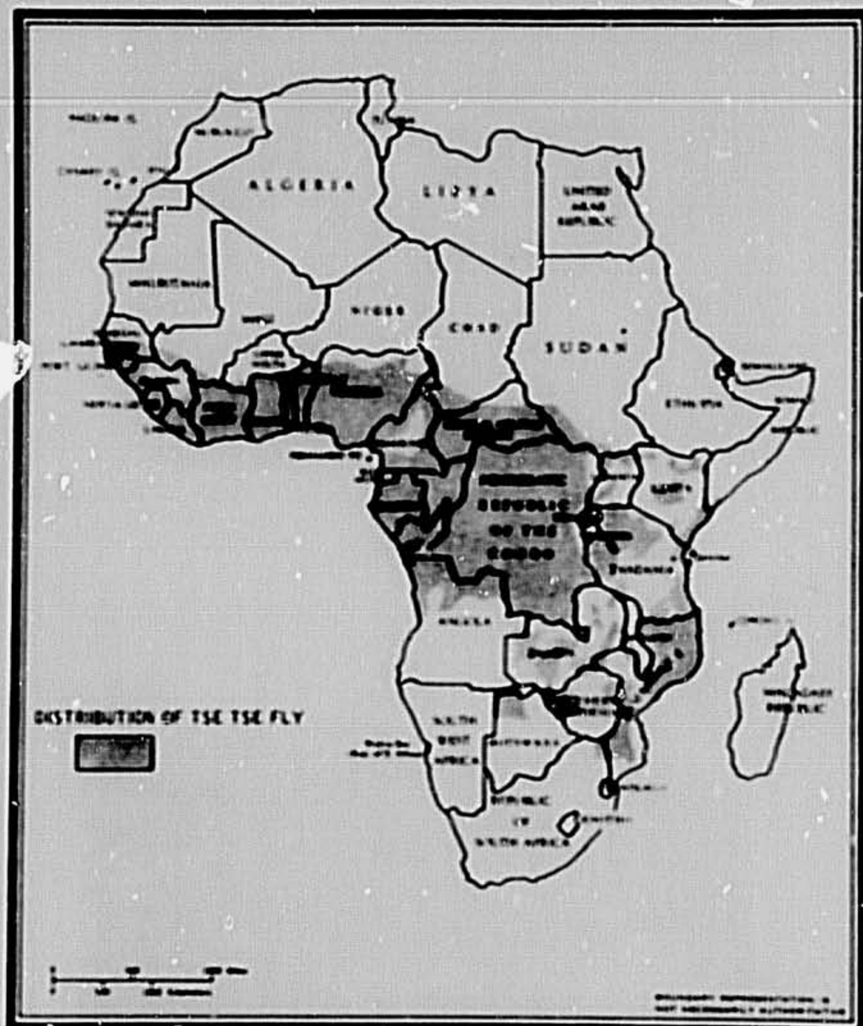

Figure 2.20 <u>The Distribution of Tsetse Fly in Africa</u>
Source: Nels M. Konnerup, "The Outlook for Animal Agriculture in Africa", *Proceedings of Agricultural Research Institute* Fifteenth Annual General Meeting, Washington, D.C., October 10-11, 1966), p. 138. (692217-1)

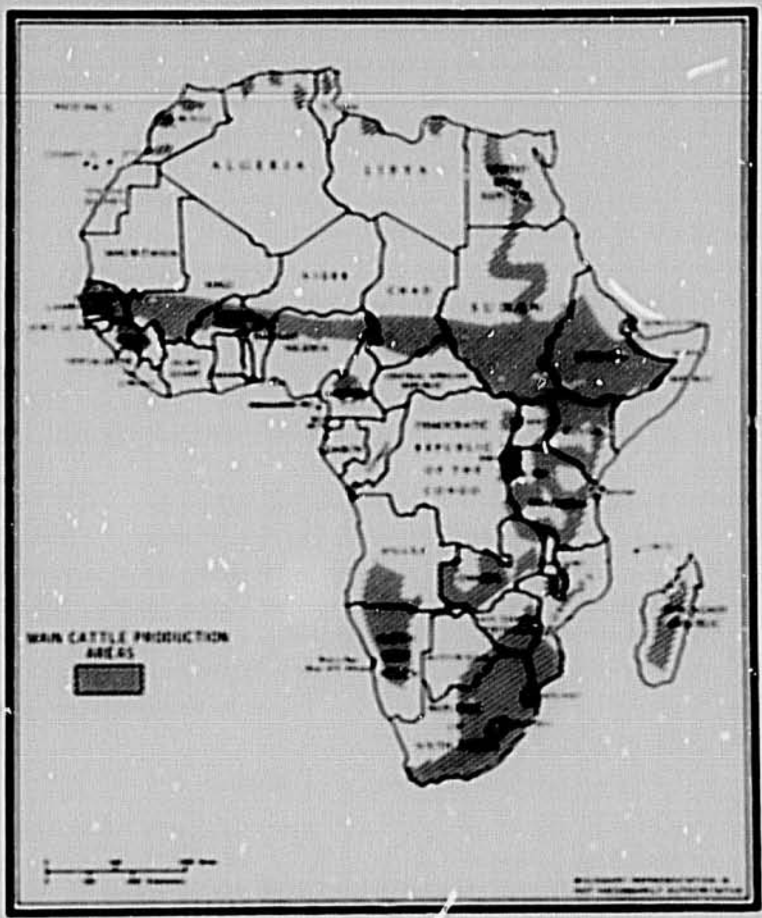

Figure 2.21 The Major Livestock-producing Areas in Africa
Source: Nels M. Konnerup, "The Outlook for Animal Agriculture in Africa" *Proceedings of the Agricultural Research Institute* (Fifteenth Annual Meeting, Washington, D.C., October 10-11, 1966), p. 136. (492217-2)

A comparison between the field rates for oxen and tractors indicates that a tractor is able to accomplish in one hour what a pair of oxen can achieve in a five-hour working day. However, *the tractor only comes into its own if its operation can be spread over a fairly large area and be used for a major proportion of the year. Tractor fixed costs are high in contrast to low oxen fixed costs.*

<u>Case Studies of Engine-powered Agriculture</u>

Observations of engine-powered agriculture have fallen into three general categories: settlement schemes, tractor hire services, and large-scale operations. The Awash Valley Authority, Middle Awash Settlement Scheme (Ethiopia), has provided detailed economic data on the development of a settlement scheme since 1967; additional technical information has been included from the experience of the Masai Wheat Scheme, Kenya, and the Block Farm Scheme, Tanzania. Information on tractor hire services has been obtained from the ministries of agriculture of Kenya, Ghana, Nigeria and Gambia, with additional conclusions from a survey by the IBRD on the East African tractor services. Information from large-scale enterprises has been obtained from three dissimilar operations: Tendaho Plantations Share Company and large-scale commercial farming located in the Setit-Humera area, both in Ethiopia; and from Motoragri in the Ivory Coast.

Tendaho Plantations and Setit-Humera both represent achievements of private enterprise; their economic motivation is that of profit. Although Tendaho is a joint venture with the Ethiopian government, the organization of both these systems of commercial farming is in the hands of private individuals. *There is a reservoir of skill and individual enterprise lying in the private sector of the country's economy which should not be overlooked* in the planning of economic development, especially if private enterprise and governments are able to coordinate their operations.

Settlements: Middle Awash, Ethiopia

The reasons for establishing the Middle Awash Settlement Scheme were mainly technical, with concomitant sociological grounds.[43] Essentially, this settlement is based on the technology of growing irrigated cotton.[44] However,

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[43] Carr classifies settlement schemes as an essential tool for development according to two categories of establishment: solely technical grounds such as irrigation of a formerly unpopulated area, movement of people from over- to underpopulated areas; and socio-political grounds such as the subdivision of large estates, the settlement of refugees and physically handicapped people, school-leavers to act as a catalyst to local farmers. Settlement schemes, however, are one of many tools in development and the schemes involve people who also have needs and aspirations to which the grounds for settlement scheme should not be unrelated.

S.J. Carr, *Agricultural Settlement in Uganda* (mimeographed), paper read at the Annual Conference of the Uganda Agricultural Society (Kampala: Makerere University College, September, 1966).

[44] Ethiopia imports a substantial quantity of cotton annually: 1961, 604 metric tons; 1965, 305 metric tons.

United Nations, *Trade Year Book*, Vol. XX, p. 290.

since the aim is to grow cotton on land formerly grazed by the herds of the nomadic Afar (Danakils), the scheme is intended to encourage a number of these people to settle and become cultivators. The sociological objectives are:

1. To improve the economic well-being of the nomads who become cultivator-settlers;
2. To improve the settlers' conditions of sanitation, and level of health;
3. To introduce needed educational and civic facilities.

Such a settlement in the middle Awash Valley facilitates adequate management of cotton production and the introduction, under close management supervision, of new capital in the form of agricultural equipment for early cultivation operations.[43] Further, with adequate management, findings of the nearby research station of Melka Werer on the productive processes can be introduced. The economic program is designed to accommodate gradually 1500 Afar families, requiring of each some 300-400 man-days of work per year. An annual income of about $180 was first considered adequate. Initial services provide mechanical cultivations, supply of consumable farm inputs, the strict control over farming operations and the marketing of cash crops. Farmers' cooperatives are being encouraged and the functional management will be reduced as settlers show themselves capable of assuming the responsibilities of management. (Figure 2.22.)

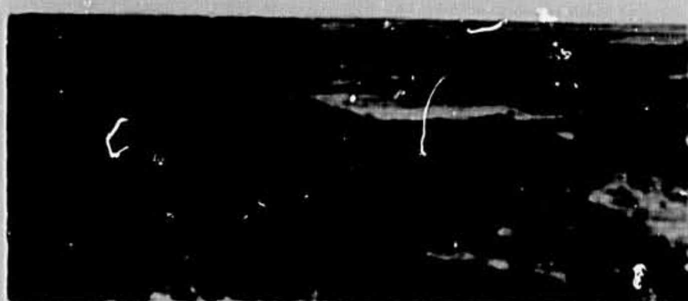

Figure 2.22 Amibara Plains (Middle Awash Settlement, Ethiopia): General view of plantation area The plains' vegetation is Acacia savannah. Trees and scrub bush are cleared by bull-dozer equipment and the land leveled for irrigation. This broad expanse of flat land is fertile and ideal for irrigated crops. The levees for irrigation control on the settlement plantation are visible behind a small group of buildings (upper right). A yield of 1500 kg/ha. for Acala 4.42 cotton is a reasonable estimate for this area. (AFB-448)

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[43] Settlements are justified in the Tanzanian Block Cultivation Schemes by the opportunities to strengthen the management function and introduce capital equipment because of larger areas of cultivation in the blocks.

J.D. Heijnen. *Some Notes on the [illegible] Block Schemes* (mimeographed) (Nyegezi, Tanganyika: 30 September, 1965), p. 1.

The People

The entire area consists of 12,000 hectares on the Amibara Plains, 300 kilometers east northeast of Addis Ababa, 750 meters above sea level with a precipitation of 350-450 mm. during the period April through August.

Some Afar people have settled in the middle and lower Awash Valley to farm the land; these groups appear to have lost the respect of other, more traditional, groups of Afar. Thus, there are strong sociological pressures to settle on those Afar who are confined to the Amibara Plains by antipathetic peoples living on the western side of the Awash River and in the surrounding highland country. The problem of inducing them to settle and change their pattern of life appears less difficult than in the lower Awash Valley (*i.e.* at the Tendaho Plantations site in the Danakil Desert).

The traditional life of the Afar is tied to cattle, camels, sheep and goats. Milk is the dietary mainstay and they eat very little meat. Settlement involves the Afar in many changes in work and food habits, and in their association with animals.

Afar villages consist of groups of small dome-shaped houses surrounded by a brush wood perimeter fence. The houses are constructed of light, easily-transportable woven grass mats erected over a framework of sticks. No concerted attempt has been made to change this traditional style of village.

Traditionally, women and children labor; men are concerned only with the movement of animals. Thus, it is not easy to persuade Afar men to work in the fields. Settlement authorities hire day-laborers from the surrounding highland population, ethnically different from the Afar. Highlanders are accustomed to field work and demonstrate to the Afar settlers some of the aptitudes which are necessary for productive field work.

Afar, as Muslims, owe allegiance to their Sultan who lives in the city of Assaita in the lower Awash Valley. Thus, this new way of life involves this particular group of settlers in conflicting loyalties: between the new and traditional ways of life and between the disciplines of economic management and the authority of their traditional social structure.

The Land and the Farm

The scheme originally was planned to allocated 5.0 hectares to each family, but it was discovered that 2.5 hectares of land was the maximum that a family could manage. In the first year of operation (1967-8), 60 Afar families settled on 97 hectares (82 hectares of cotton and 15 hectares of maize) or 1.367 hectares of cotton and 0.25 hectares of maize per family. Cotton provides cash income; maize is grown for family consumption. The scheme was designed to allocate 2.5 hectares of cotton and 0.5 hectares of maize for each family, but now it is believed that the cotton allocation is excessive, so 0.25 hectares of groundnuts (which requires less labor) may be

introduced to replace 0.25 hectares of cotton.

In the first year of the scheme, 300 hectares of land were cleared and prepared for irrigation from the Awash River, on the west flank of the plantation. However, due to delay in obtaining equipment, only 97 hectares were cultivated. In the second season, a new 300 hectares were cleared and the 600 hectares were cultivated. The settlement area consisted of 67 settler families, each with 2.5 hectares (total: 167.5 hectares); the land balance (432.5 hectares) was farmed directly by the AVA. There is now sufficient cleared land to accommodate 240 families. Under the original plan of expansion to accommodate 1500 families, 7500 hectares could have been occupied, but on the capability basis of 2.5 hectares per family only 3750 hectares will be occupied. For the present, no long term plans exist to expand the number of families settled or to incorporate more land. Planning is based on the availability of funds from the annual budget.

In this discussion, two possible farm organizations are considered. The first is the actual operating experience in the first and second years, and the second is the operation of the farm incorporating 0.25 hectares of groundnuts into the scheme.

Crops and Cultivation Practices

The first season of operation gained experience on 97 hectares. The clearing of 300 hectares began in May, 196[illegible] and was followed by subsoiling, leveling, seedbed preparation and bordering for irrigation.

Following seedbed preparation, cotton and maize were planted from late September to late October. In September, Acala cotton 1517C was planted on 42 hectares at a rate of 28.8 kilograms per hectare; in October, Acala 4.42 was planted on 40 hectares at the same seeding rate, and 170 White Regular maize was planted on 15 hectares at a rate of 23.3 kilograms per hectare. These rates are considerably reduced in the second annual budget.

Weeding and thinning followed in November and December. The only tool employed is a small sickle to scrape up weeds between the rows of young plants. Inter-row cultivation proceeded along with hand weeding.

Irrigation was carried out four times on the 40 hectare plot and five times on the 42 hectares during the period from early September to early January.

Insecticides spraying took place during November and December. A total of five aerial sprays on the 42 hectares and three sprays on the 40 hectares were applied.

Three pickings took place, between the third and fourth irrigations, between the fourth and fifth irrigations, and a final picking in January.

The calendar distribution of these cropping operations is shown in Table II.29.

TABLE II.29 MIDDLE AWASH SETTLEMENT: DISTRIBUTION OF CROPPING OPERATIONS

Field size	42 hectares	40 hectares	15 hectares
Crop	Cotton: Acala 1517C	Cotton: Acala 4.42	Maize: White Regular 170
Year	1967	1967	1967
Operations			
Precultivation	5-10 August	10-25 September	10-25 September
Disk-bordering	10-15 August	1-10 October	1-10 October
Planting	13 Aug. - 2 Sept.	13-22 October	27-28 October
Inter-row cultivation	1-5 September		
Weeding	15-30 September	25 Nov. - 17 Dec.	20 November
Inter-row cultivation	25-30 September		
Thinning	15-30 September		
Irrigation (1)	17-26 September	2-22 October 1-10 November	15 November
Inter-row cultivation		15-22 November	
Irrigation (2)	27 Sept. - 9 Oct.	7-29 November	8-11 November
Inter-row cultivation		13-26 December	
Irrigation (3)	23 Oct. - 8 Nov.	22 Dec. - 1 Jan., 1968	22-29 November
Irrigation (4)	30 Nov. - 10 Jan. 1968	11 Jan., 1968	

Calendar of Operations

Clearing operations were completed as planned for both seasons. Inexperience and a late start in the first season resulted in only 97 hectares actually being planted during first season; also clearing and land development costs were much higher on the first 300 hectares due to both inexperience and that area being more heavily wooded. Development cost differences (1968 costs were only 32 percent of 1967 costs) are illustrated by the data shown in Table II.30.

Development costs are overhead charges borne by the settlement scheme on a pro rata basis. Depreciation is charged at \$18.00[44] per hectare under cultivation for the first two years of operation.

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[44] The actual value is \$18.82 but this is high since depreciation is also computed in the development costs. Therefore, it was rounded to \$18.00 which is close to the cost used by AVA. This figure was computed on an equal installment basis by depreciating crawler tractors in five years, wheel tractors over six years, pumps over five years, and other equipment over 12 1/2 years. The development costs are amortized at 6 percent per annum over 20 years, thus charging \$12.93 per annum against the old 300 hectares (97 hectares in first year) and \$5.97 per annum against the new 300 hectares.

TABLE II.30 MIDDLE AWASH SETTLEMENT: DEVELOPMENT COSTS, 1967 AND 1968

Operation	1967 Old 300 Hectares				1968 New 300 Hectares			
	Hrs.	Rate Per Hr.	Total	Per ha.	Hrs.	Rate Per hr	Total	Per. Ha.
	- - - - - - - - - - - -			dollars	- - - - - - - - - - - -			
A. Caterpillar (D-6)								
Cleaning	1680	9.27[a]	15,573	51.99	493	9.27[a]	4,570	15.31
Leveling	566	9.27	5,247	17.33	490	9.27	4,542	15.31
Canals	435	9.27	4,032	13.30	663	9.27	6,146	20.36
	2681		24,852	82.62	1646		15,258	51.18
B. Wheel-tractors								
Subsoiling	886	3.22[b]	2,857	9.47	453	3.22[b]	1,461	4.84
Leveling	497	3.22	1,602	5.24	235	3.22	758	2.41
Ditching	88	3.22	284	0.81	2	3.22	6	—
	1471		4,743	15.72	690		2,225	7.25
C. Labor	man-days	per m.d.			man-days	per m.d.		
Clearing and canal construction	1418	0.61	8,897	29.82	1735	0.61	10,490	3.63
D. Total clearing cost per ha.				128.16				62.06
E. Road construction				20.15				6.45[c]
F. Total development cost per hectare				148.31				68.51
G. Amortization (x 0.08718)				12.93				5.97

[a]Cost of crawler operation $8.69, plus cost of implement depreciation, $0.58.

[b]Cost of wheel tractor operation, $2.92, plus cost of implement depreciation, $0.30.

[c]Estimated on the basis that 1968 costs were 32 percent of 1967 costs.

In addition to machinery and clearing the settlement needs certain buildings, vehicles and local management personnel. All variable and overhead costs are charged against the settlement's income except costs for local management. It is the intention to cover these costs as nearly as possible without penalizing the settlers for heavy administrative costs in the early years of operation. Estimated administrative overheads are summarized in Table II.31.

TABLE II.31 MIDDLE AWASH SETTLEMENT: ESTIMATES OF COSTS FOR LOCAL MANAGEMENT

Cost	Annual Charge
Running expenses	
Fuel and oil for vehicles and generators, repairs and spares, transport from Addis Ababa to Amibara	$14,106
Depreciation	
Building, fittings, generators, vehicles	8,061
Salaries	
Twenty management and technical staff, labor assistance	27,873
Total	$50,040

The activities of the settlement are roughly divided among clearing, preparing the land, and growing crops of cotton and maize. The distribution of operations over the calendar year is shown in Table II.32 which also includes rainfall and temperature data.

TABLE II.32 MIDDLE AWASH SETTLEMENT: CALENDAR OF OPERATIONS

Item	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total & Mean
Mean rainfall (mm.)[a]	3.2 (1)[b]	4.7 (1)	52.2 (3)	38.2 (3)	29.5 (2)	16.6 (2)	86.0 (0)	189.8 (3)	50.8 (3)	12.2 (2)	56.1 (2)	0.0 (0)	539.3
Mean temperature[a] 1965-67* (°C)													
Minimum	14.9	16.9	18.5	21.0	20.7	24.7	23.1	21.3	21.3	18.5	17.8	13.5	19.4
Maximum	29.6	30.3	30.9	31.0	33.5	34.2	32.9	30.5	30.3	30.9	29.1	29.0	30.1
Crops and operations			survey dyke construction		clear stake								
Land preparation (old 300 ha. -- 1968)			repair dykes										
Land clearing and preparation			rough level subsoil level design			survey and stake dyke construction irrigation structure							
Maize and Cotton (preparation)				preculti vate and ridge		pre-irrigation	irrigation and plant (Blocks irrigated for 1 wk., planting 2 days.	reridge		harvest			
Maize (irrigate, weed, harvest)							irrigate & weed		harvest				

(Table continued.)

TABLE II.32 (continued)

Item	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total & Mean
Cotton (weed, cultivation, irrigate & pick)	pick					thin, weed weed & interrow cultivation before irrigation			irrigation	irrigate & weed	irrigate & pick	irrigate & pick	
Groundnuts[c]	irrigate	pick							preplant preparation & irrigation	plant, irrigate, weed & thin	weed & irrigate	irrigate	

[a]Melka Werer Research Station, *Progress Report for the Period February, 1966 to March, 1968* (mimeographed) (Addis Ababa: Institute of Agricultural Research, 1968), p. 4.

[b]Number of years out of three in which rain fell, 1965-67.

[c]Groundnuts (peanuts) not yet grown on Settlement.

Labor Distribution

Typical man-day requirements for the cultivation of crops are given in Table II.33. This is necessary information for planning the labor distribution requirements for expanding the settlement scheme.

TABLE II.33 MIDDLE AWASH SETTLEMENT: LABOR REQUIREMENTS FOR TYPICAL CROPS

Operation	Cotton	Maize	Groundnuts
	- - - man-days per hectare - - - - - - - -		
Preplanting	10	10	12
Irrigation	32	20	32
Weeding	30	24	16
Thinning	5	-	4
Picking	75	-	20
Harvesting and transport	-	24	-
Total	152	78	84

Labor requirements are set out in Table II.34 for the three types of farm: 1.617 hectares in 1967-8; 3.00 hectares in 1968-9; and 3.00 hectares incorporating 0.50 hectares of groundnuts. From these data it is clear that picking and harvest periods demand the highest labor contribution from the family. Any month with over 70 man-days needs a minimum of three adult working members in the family. Since few families include so many, a substantial employment of day-labor in November and December is needed. The reorganization of the 3.00 hectare farms to accommodate 0.50 hectares of groundnuts, however, results in a substantial decrease in labor requirements except for the month of November.

Other Inputs

Day labor is hired during peak labor seasons. The laborers are highland people who actually are much more productive than the settlers. During weeding, payment is made at the rate of $0.66 per row (approximately 100 meters long). Highlanders can work 1 1/2 rows and Afars about one row per day; thus the rate of payment is about $1.00 per day. During the picking season, workers are paid $0.022 per kilogram, and work at an average picking rate of 45 kg./day for highlander.

Yields of Main Crops

1) Cotton

In the settlement accounts shown in Table II.35 the recorded yield of cotton for the 1967-8 season amounts to 18.03 q./ha. and in the estimated account for the 1968-9 season, the yield is based on 15 q./ha. Related to the cotton

TABLE II.34 MIDDLE AWASH SETTLEMENT: ESTIMATED ANNUAL DISTRIBUTION OF LABOR REQUIREMENTS

Crop	Ha.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
		man-days per month												
1967-8 Cotton	1.367	[illegible]34.1					pr:13.7	i: 3.5 t: 6.8 w:13.7	w:13.7	i:10.9	i:10.9 w:13.7	i:10.9 pi:34.2	i: 5.5 pi:34.2	207.8
Maize	0.250					pr: 3.0 i: 1.0	i: 2.0 w: 3.0	i: 2.0 w: 3.0		h: 6.0				20.0
Total	1.617	34.1				4.0	18.7	31.0	13.7	16.9	24.6	45.1	39.7	227.8
1968-9 Cotton	2.50	pi:62.5					pr:25.0	i:10.0 t:12.5 w:25.0	w:25.0	i:20.0	i:20.0 w:25.0	i:20.0 pi:62.5	i:10.0 pi:62.5	380.0
Maize	0.50					pr: 6.0 i: 2.0	i: 4.0 w: 6.0	i: 4.0 w: 6.0		h:12				40.0
Total	3.00	62.5				8.0	35.0	37.5	25.0	32.0	45.0	82.5	72.5	420.0
Cotton	2.25	pi:36.25					pr:22.5	i: 9.0 t:11.25 w:22.50	w:22.5	i:18.0	i:18.0 w:22.5	i:18.0 pi:36.25	i: 9.0 pi:36.25	342.0
Maize	0.25					pr: 3.0 i: 1.0	i: 2.0 w: 3.0	i: 2.0 w: 3.0		h: 6.0				20.0
Groundnuts	0.50	i: 2.0	pi:10.00							pr: 6.0 i: 2.0	i: 4.0 t: 4.0 w: 4.0	i: 4.0 w: 4.0	i: 4.0	42.0
Total	3.00	38.25	10.00			4.0	27.5	47.75	22.5	32.0	50.5	82.25	69.25	404.0
Labor per hectare Cotton	1.00	pi:25					pr:10	i: 4 t: 5 w:10	w:10	i: 8	i: 8 w:10	i: 8 pi:25	i: 4 pi:25	
		25					10	19	10	8	18	33	29	152
Maize	1.00					pr:12 i: 4	i: 8 w:12	i: 8 w:12		h:24				
						16	20	20		24				80
Groundnuts	1.00	i: 4	pi:20							pr:12 i: 4	i: 8 t: 4 w: 8	i: 8 w: 8	i: 8	
		4	20							16	20	16	8	84

Key: pr: precultivation; i: irrigation; t: thinning; w: weeding; pi: picking; h: harvesting.

TABLE II.35 MIDDLE AWASH SETTLEMENT: TOTAL PRODUCTION AND SEED RATES FOR 1967-68 AND 1968-69 SEASONS AND ONE POSSIBLE LEVEL OF PRODUCTION INCORPORATING GROUNDNUTS (PEANUTS)

Crop	Area	Yield	Total Product	Market Price	Total Value Product	Seed Rate	Total Seed	Market Price	Total Seed Cost
	1967 - 1968 season								
	ha.	q./ha.	quint.	$/q.	$	kg./ha.	quint.	$/q.	$
<u>Average farm</u>									
Cotton	1.367	18.03	24.64	24.14[a]	593	28.86	.395	43.7	17.24
Maize	0.250	25.00	6.25	4.84	30	23.3	.058	73.4	4.28
Groundnuts	-	-	-	-	-	-	-	-	-
Total	1.617				623				21.52
Gross Cash Income[b]					593				
<u>Total Settlement</u>									
Cotton	82	18.03	1478	24.14[a]	35,680	28.56	23.50	43.7	1027
Maize	15	25.00	375	4.84	1,800	23.3	3.50	7.34	257
Groundnuts	-	-	-	-	-	-	-	-	-
Total	97				37,480				1284
Gross Cash Income[b]					35,680				
	1968 - 1969 season								
<u>Average farm</u>									
Cotton	2.50	15.00	37.50	24.18	907	25.0	.625	10,07	6.29
Maize	0.50	25.00	12.50	4.84	70	40.0	.200	10,07	2.01
Groundnuts	-	-	-	-	-	-	-	-	-
Total	3.00				977				
Gross Cash Income[b]					907				
<u>Total Settlement</u>									
Cotton	570	15.00	8550	24.18	206,751[c]	25.0	142.50	10,07	1436
Maize	30	25.00	750	4.84	3,627[c]	40.0	12.00	10,07	121
Groundnuts	-	-	-	-	-	-	-	-	-
Total	600				210,378				1557
Gross Cash Income[b]					206,751				

(continued on the next page.)

TABLE 11.35 CONTINUED

Crop	Farm Incorporating Groundnuts								
	Area	Yield	Total Product	Market Price	Total Value Product	Seed Rate	Total Seed	Market Price	Total Seed Cost
	ha.	q./ha.	quint.	$/q.	$	kg./ha.	quint.	$/q.	$
Average farm									
Cotton	2.25	20.00	45.00	24.18	1088	25.0	.56	10.07	5.64
Maize	0.25	40.00	10.00	4.84	48	40.0	.10	10.07	1.00
Groundnuts	0.50	17.00 (shelled)	8.50	14.11	120	50.0	.25	16.12	4.03
Total	3.00				1256				10.67
Gross Cash Income[b]					1208				
Total Settlement									
Cotton	750.00	20.00	15,000	24.18	362,700	25.0	187.5	10.07	1,888
Maize	83.3	40.00	3,332	4.84	16,127	40.0	33.3	10.07	335
Groundnuts	166.7	17.00	2,834	14.11	39,999	50.0	83.4	16.12	1,344
Total	1000				418,826				3,567
Gross Cash Income[b]					402,669				

[a]Average price computed from data in Table 11.36 for 1967-8 season.

[b]Sum of incomes from marketable cash crops.

[c]Small discrepancies occur between unit price and total value product due to conversion into U.S. currency.

trials for the area for Acala 1517C and Acala 4.42[47] a yield of 15 q./ha. is a reasonable assumption for the purpose of estimating future operations even with inexperienced settlers. Closely managed private commercial farmers can produce over 20 quintals per hectare under similar conditions in the same area.

2) Maize (corn)

The accounts in Table II.33 use a yield estimate for maize of 25 q./ha. Ordinary open pollinated maize was employed during the first year of operation and during the second year hybrid corn was grown with an estimated yield approaching 30 q./ha. Again this assumption is well within the possibilities suggested by local trials of 170 White Regular maize.[48] There is some evidence that yields of 40 q./ha. may be a possibility. If this is realized then sufficient maize can be grown for family needs on 0.25 hectares (1,000 kilograms per family). Growing maize on 0.50 hectares will produce a surplus which can be sold or used for feed if a local cattle raising enterprise could be established.[49]

3) Groundnuts (peanuts)

A goal of 2.50 hectares of cotton is too much for one settler family to handle. Thus, there are plans for growing 2.25 hectares of cotton, 0.5 hectares of maize and 0.25 hectares of groundnuts. An appropriate yield would be 17 q./ha. (up to 37.4 q./ha. has been recorded for the Dire Dawa variety).[50]

Livestock

No attempt has been made to incorporate the important Afar animal husbandry into the settlement scheme. If the plan to develop the range land of the adjacent Aledehgi Plain receives support, it is believed that the growing of lucerne grass (alfalfa) can be incorporated into the settlement cropping program to provide a source of good quality hay for plains cattle.

Estimated Annual Production

The settlement area is being expanded gradually to accommodate more families. Since each farm is the same size, a more precise picture of total production is possible on the basis of an average farm. Total production per farm for the first and second season with a possible change to incorporate

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[47] Melka Werer, *op. cit.*, p. 13.

[48] *Ibid.*, p. 23.

[49] There are plans to establish a cattle improvement scheme on the adjacent Aledeghi Plains to the northeast of Amibara.

[50] Melka Werer, *op. cit.*, p. 33.

groundnuts, is set out in Table II.35. This last budget assumes the most optimistic situation: maize yield, 40 q./ha.; cotton yield of 20 q./ha.; groundnut yield 17 q./ha. (shelled). The settler area is assumed to be 1000 hectares, to accommodate 333 families.

<u>Costs of Production</u>

From the experience of the 1967-8 cropping season and the data already discussed, costs of production for the 97 hectares under full cultivation can be determined and the costs budgeted for the 1968-9 season (570 hectares of cotton, 15 q./ha.; 30 hectares of maize, 25 q./ha.) The calculations are set out in Table II.36.

For the second year, the number of families was assumed to be the equivalent of 240, the settlement allotments being completely taken at the rate of 2.5 hectares per family. However, some families (67) were accounted for as full settlers and the balance (173) tentative laboring families not yet fully approved as settlers. The account shows that by the end of 1968-9 year, the settlement scheme will meet the full costs of administration and supervision and raise the income of the settled families from $180 to $240 as an incentive to continued settlement.

The Middle Awash Valley Settlement Scheme demonstrates that inexperienced farm settlers may be introduced gradually to the complexities of mechanized agricultural technology of large-scale cotton production. The scheme still faces difficulties, especially in maintenance of high caliber management in the relatively isolated area.

There are several major considerations which favor the success of this settlement. Firstly, the area is sparsely populated and, apart from being a traditional grazing area, it is undeveloped in any way. There is the problem of displacing local herdsmen, but these people are the ones being encouraged to settle. Secondly, the *raison d'être* of the scheme is the settlement of the nomadic Afar people to insure a more abundant form of living in an area where the social pressures are tending increasingly to supress traditionally nomadic peoples. Thirdly, the scheme is based economically on cotton production in a relatively fertile area of the country. There is good internal demand for cotton in Ethiopia[51] although, due to the distance from Addis Ababa, the marketing process has transportation and communication problems.

The development of the settlement is rather flexible with planning from year to year rather than attempting to maintain a long range plan of expansion.

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[51] Ethiopia paid foreign exchange for imported cotton as follows: 1964, $2.407 M.; 1965, $1.743 M.; 1966, $3.967 M.
Imperial Ethiopian Government, *Statistical Abstracts*, 1966, p. 103.

TABLE II.36 MIDDLE AWASH SETTLEMENT: INCOME AND EXPENDITURE ACCOUNT FOR 1967-68 AND ESTIMATE FOR 1968-69

	1967-68 Season (97 hectares)[a]					1968-69 Season (600 hectares)[b]				
	Expenditures			Income (actual)		Expenditures			Income (estimated)	
		dollars			dollars		dollars			dollars
Income										
Sales proceeds:										
Cotton ($24.18/q.)				1418 q.	34,302				8550 q.	206,751
Maize ($4.84/q.)				373 q.[c]	1,800				750 q.	3,627
Stock:										
Cotton ($22.97/q.)				60 q.	1,378					
Expenditures						Dollars/ha.[d]				
Seed: Cotton	2350 kgs.	1027				(2.52)	1436			
Maize	350 kgs.	257	1,284			(4.03)2.60[e]	131	1,557		
Insecticides:										
Liquid	17690 l.	2675				22.97		13,783		
Solid	420 kgs.	438				(threshing				
Time	10	48	3,163			maize) 00,25[e]		151		
Aerial sprays	8 times		798			9.27[e]		5,561		
Fuel: tractors		715				7.37	4422			
pump		1108	1,823			11.42	6852	11,274		
Salaries:										
Drivers'		949				9.78	5868			
Pump operators'		609	1,558			6.28	3768	9,636		
Additional labor			5,238			54.00		32,400		
Total direct costs			13,864			$123.94/ha.		74,362		
Depreciation on										
cultivation	97 ha. x 18.00		1,746			600 x 18.00		10,800		
Spares and repairs	97 ha. x 16.12		1,564			600 x 16.12		9,672		
Royalties	97 ha. x 0.403		39			600 x 0.403		242		
Amortization of						300 x 12.93	3879			
development cost	97 ha. x 12.93		1,254			300 x 5.97	1791	5,660		
Total direct and			18,467					100,736		
development costs										
Families' incomes	60 x 180[e]		10,800			67 x 240[f]	16080			
						173 x 180[g]	11140	47,220		
			29,267			240 families		147,956		
Balance: to super-										
vision cost			8,193					62,422		
			37,480		37,480			210,378		210,378

(See notes on the next page).

[a]97 hectares: cotton, 82 hectares; maize, 15 hectares.

[b]600 hectares: cotton, 570 hectares; maize, 30 hectares.

[c]This item is a notional income since maize is not a cash crop.

[d]Computed from 1967-8 operation.

[e]Weighted average.

[f]Income raised from $180 in 1967-8 to $240 in 1968-9 as an incentive to continue settlement.

[g]This item is introduced to allow for the fact that if all the area is settled then the minimum cash income must be found for 173 more families than actually were settled.

Hence, there is no steady pressure to expand. Proximity to Melka Werer Research Station is advantageous. *The first year the settlement acted as a project and the station has facilities to experiment both with new crops and the optimum cultivation practices for established crops from which the settlement can obtain important technical information.*

Settlements: Masai Wheat Scheme, Kenya

As currently administered by the Mechanization Section of the Soil Conservation and Planning Unit of the Kenya Ministry of Agriculture, the Masai Wheat Scheme in Western Kenya is a good example of planning mechanized agriculture in a previously undeveloped area. Since its inception in 1967 the MOA, with the technical advice of Downing, an FAO mechanization specialist, has brought about 6075 hectares under cultivation with a minimum investment in 50 tractors and companion machinery. The operation is completely mechanized from initial clearing and soil-breaking to harvest, and MOA furnishes all equipment and staff to produce wheat for the Masai land owners. Detailed cost records are kept and charges are assessed against the gross return. So far, yields have been outstanding (running from 27 q/ha. to 40 q/ha.) on this virgin land where a form of minimum tillage is employed to keep operating costs low (no fertilizers are used). The profit accruing to the Masai land owners has been very substantial. There is some concern that the Masai people may expect all future operations to be as profitable and that the government will be obligated to continue this operation to the advantage of the Masai. Future overhead costs are apt to be heavier and will have to be charged since current charges make insufficient allowance for replacement of equipment or the costs of managerial and technical assistance.

So far machinery utilization has been good, with an average cultivated area of around 120 hectares per tractor. Productive hours per tractor averaged 86 percent annually of total running time, possibly with higher efficiency in the first than the second year. Combines are used for harvest and it is not uncommon for a 3.7-meter machine to cover 1200 hectares in one season. Due to differences in altitude the season is staggered, thus, planting and harvesting dates extend over a considerable period. Most of the wheat land is between 1,800 and 2,800 meters elevation. At the time of the Team's visit, combining was nearing completion at 3,000 meters elevation, while soil-preparation for the new planting was underway at lower and higher elevations. (Figure 2.23 and 2.24).

Downing also is conducting experiments on 304 hectares to determine production costs using four basic machines for soil preparation: namely, a three- to four-bottom disk and moldboard plow, an eight- to ten-tooth chisel plow; and a large, one-way, wide, level-disk plow. The latter plow is an Austrian-made Connor-Shea model with 14 independently spring-loaded disks. Although quite

expensive, it does an excellent job on fairly rough land, and with its high capacity produces a very low cost seed-bed.

The Vertisol soils in East Africa are highly friable with self-mulching characteristics. There is danger in overworking the soil, and extreme pulverizing occurs with excessive handling.

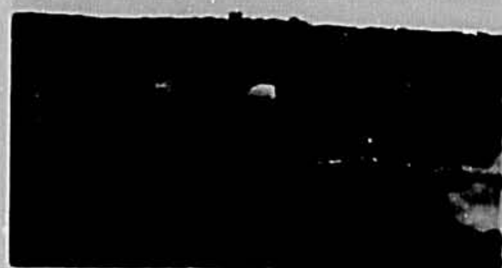

Figure 2.23 The Mosoi Wheat Scheme (Kenya): Land preparation Heavy disks are used to prepare the land for planting wheat. The equipment shown in this figure is in operation at an elevation of 1800 meters in February. The land has lain idle for several months during which time much volunteer growth appears which is cut and buried during two disking operations. As the season progresses the heavy disks gradually move to work at higher elevations until wheat has been planted over the entire range of altitude from 1800 up to 2800 meters. (AFR-101)

Figure 2.24 The Mosoi Wheat Scheme (Kenya): Combine harvesting Combine harvester made by Claas is capable of harvesting 1200-1500 hectares of wheat each season. This large capacity is made possible by wheat cultivation being spread over a range of altitudes from 1800 to 2800 meters. Combine harvesting was in operation simultaneously with the disking shown in Figure 2.23. (AFR-103)

Settlements: Block Cultivation Scheme, Tanzania

<u>The Scheme and the Environment</u>

Block cultivation schemes were introduced into Sukumaland during 1964-65. The government had turned over to the Victoria Federation of Cooperative Unions 159 Ferguson and Fordson Major tractors in the previous year.[52] The objective of these schemes was to use the tractors economically by amalgamating cotton fields into 121.4 hectare blocks.[53]

1) The Area

Sukumaland covers 44,030 square kilometers extending inland from the southern and southeastern shores of Lake Victoria. The country lies at an altitude of 1100 to 1450 meters and is comprised of a considerable variety of soils: light sandy to heavy impermeable black cotton soils. The land is gently undulating with occasional granite out-crops. There are some 3.5 million cattle and three million sheep in the area.[54]

2) Farm Blocks

The establishment of these mechanized farm blocks was based on the assumptions of labor scarcity in the region and that additional land can only be cultivated with economical assistance. Capital is scarce and it appeared uneconomical to substitute capital in the form of engine-powered equipment for hand labor; rather capital should be employed only to supplement available family labor in order to extend the cultivated area. It was also assumed that adequate supervision can be provided to improve cultivation practices and demonstrate the use of fertilizers (the block farms offer excellent scope for demonstrations) by the extension service; and that economies of scale can be effectively realized by farming the land in large blocks.[55] Thus it was expected to increase the area that each family could cultivate without increasing the labor requirements from the family. Increases in cotton yields were anticipated (from around 4.48 to 11.20 q/ha.) by the supervised use of fertilizer, insecticides and improved cotton varieties.

3) Supervision

The organization of the scheme was entirely in the hands of the extension staff while the task of persuasion was undertaken by the official political party (TANU). *Supervision proved inadequate despite a majority (60-65 percent) of all extension workers in the country being employed on this scheme; moreover,*

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[52] John C. de Wilde *et al.*, *Experiences with Agricultural Development in Tropical Africa*, Vol. II, *The Case Studies* (Baltimore: The Johns Hopkins Press, 1967), p. 437.

[53] M.P. Collinson, *Economics of Block Cultivation Schemes* (mimeographed) (Ukiriguru, Tanzania: Western Region Research Center, 1965), p. 1.

[54] De Wilde, *op. cit.*, p. 415.

[55] Heijnen, *op. cit.*, pp. 1-2.

only one percent of the total farmers in the area were affected. Organizational effort involved in the selection of the blocks, mobilization of participating farmers and the timely deployment of tractors were all factors which impeded the successful development of the scheme.[56] Bulk purchase orders for tractors amounted to 373 in 1963 and 673 in 1964. Following this experience of tractor operations until 1968, Tanzanian official policy reverted to the encouragement of oxen cultivation and government-owned tractors were being sold to private commercial operators.

The scheme was difficult organizationally and a disappointment technically. The costs by Collinson were based on 575-825 tractor operating-hours per annum.[57] Evidence suggests that tractors did not reach this level of operation,[58] but standard depreciation estimates were based on 1200 operating-hours per annum.

4) Shift in Cost Structure

The form of agriculture envisaged in the block farms involved a shift from "low cost production, profitable with low returns, to high cost production, requiring high returns."[59] This form of change necessitates a substantial improvement in crop yields. The most important aspect of block cultivation probably lies in enabling families to cultivate larger areas of land. However, in order to maintain income and meet new level of operational costs, cotton yields must increase to between 9.24 and 11.94 q/ha., depending on the concomitant increase in the area of cotton grown.[60] Cotton yields on 1,947 hectares in the Mwanza Region averaged only 4.65 q/ha. compared with cultivation costs equivalent to a yield of 4.77 q/ha.; and on 365 hectares in the Shinyanga Region yields averaged 2.97 q/ha. compared with cultivation costs equivalent to a yield of 2.44 q/ha.[61] Since participating farmers were guaranteed the income from 1.82 quintals before requiring payment on any incurred costs, the recovery of a substantial amount of the expenses is doubtful.

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[56] De Wilde, *op. cit.*, p. 438-440.

[57] Collinson, *Economics of Block Cultivation Schemes*, p. 6.

[58] De Wilde notes that for the 30 block farms selected in 1964/65 totaling 16,592 hectares (41,000 acres) only 5,538 ha. (13,686 acres) were cleared and 3,232 ha. (7,987 acres) planted amounting to about 27 ha. (67 acres) planted per tractor. Cultivation, fertilizer and spraying costs were extremely high. *op. cit.*, p. 439, n. 27.

[59] John A. Pupius, *The Effects of Block Mechanization Schemes on Cotton Production within the Lake Region* (mimeographed) (Ukiriguru, Tanganyika: Western Region Research Center, 1964), p. 4.

[60] *Ibid.*, pp. 4-5.

[61] De Wilde, *op. cit.*, p. 439.

De Wilde suggests that time and trial can overcome many of these problems but these problems have been aggravated by hasty improvisation. *The importance of initial pilot schemes to test a number of variations in cultivation practices is quite apparent:*

> . . . pilot projects . . . could well be much more effective and certainly much less costly in testing out the feasibility and economies of new systems of cultivation. In such pilot projects it might well be advisable to introduce a number of variations in approach for the sake of arriving at one that is likely to be most economic and appealing under a given set of circumstances. We would not accept the premise, for example, that mechanization is the only possible solution that needs to be tested. Many parts of Sukumaland appear to be well suited to the use of ox-drawn implements whose use entails little foreign exchange drain and does not pose difficult managerial and technical problems, and which leave the individual Sukuma farmer a good deal more independent.[62]

<u>Appropriateness</u>

There is an important place for both animal-powered and engine-powered technology, and the optimum solution can be gradually "approached only through successive approximations and substitutions of various factors at the margin".[63] There are certain natural conditions in the area which obviously appear "more favorable to mechanization than in many parts of sub-Saharan Africa":[64] tree cover in the area is sparse and, since land is not very scarce, the system of tenure is flexible. It appeared that this type of development program was entirely appropriate to the area.

<u>Constraints on the Expansion of the Small Farm</u>

The following example of a family farm illustrates the labor requirements of the typical cropping pattern, and shows how mechanization of preparatory operations can be appropriately introduced into a hand-farming system to facilitate a cropping pattern in which labor requirements exceed the available labor provided by the unassisted family.[65] The operations for a small family farm growing food crops and cotton as the only cash crop are shown in Table II.37.

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[62] *Ibid.*, p. 440.

[63] *Ibid.*, p. 442.

[64] *Ibid.*, p. 438.

[65] The example is based on the data contained in two papers by Collinson: *Economics of Block Cultivation Schemes*, pp. 2-5 and *Farm Management Survey No. 3*, pp. 28 and 46.

TABLE II. 37 SUKUMALAND (MASWA DISTRICT): CROP OPERATIONS AND CALENDAR

Crop	Operation								
	Plow	Ridge	Plant	Weed		Pick or harvest			Shell, Thresh, Grade
				First	Second	First	Second	Third	
Food Crops									
Maize	Dec.-Jan.		Dec.-Jan.	Jan. Feb.		June-July			Aug.
Sorghum	Nov.-Dec.		Nov.-Dec.	Jan.-Feb.		June-July		Aug.	Aug.-Sept.
Groundnuts	Dec.-Jan.		Dec.-Jan.	Jan.-Feb.		May-June	July	Aug.	Aug.-Sept.
Cowpeas	Nov.-Dec.		Dec.-Jan.	Feb.		May			June
Sweet Potato	Dec.-Jan.	Dec.-Jan.	Dec.-Jan.	Jan.-Feb.		taken as required			
Cash Crop									
Cotton	Dec.-Jan.		Dec.-Jan.	Jan.-Feb.	Feb.-Mar.	June-July	July-Aug.	Aug.	July- Sept.

Table II.38 sets out the labor requirements for this typical cropping pattern, assuming the family to have the equivalent of three laborers and maximum working days set at the number of days in the month. With this amount of labor used on food crops there is sufficient family labor remaining to cultivate 1.09 hectares (line 4) of cotton. This area is shown under December, the month of maximum labor requirements. Thereafter, adequate labor is available to expand the cash crop only if some form of assistance is available for the month of maximum labor demand. When the constraint of December labor requirements is completely removed, available family labor is then sufficient to cultivate an additional 1.07 hectares of cotton (line 8); July labor requirements then become the constraint.

Assuming a yield of 11.12 quintals per hectare 11.90 quintals of additional cotton is produced which must have a value at least sufficient to pay for the additional cost of hired assistance. The December labor constraint operates during the cultivation period and, in the block farm scheme, engine-powered implements were made available to overcome this constraint.

The Case for Mechanization

The computations in Table II.38 demonstrate that possibility of hired engine-powered cultivation during December shifts the constraint on the size of the farm. Since cotton picking will not be mechanized for a long time in this situation, the only possible way of increasing the cotton area any further is to improve the rate of hand picking. Picking the additional cotton area is at an estimated rate of 4.8 to 9.1 kg. per man-day. In fact, this level of achievement in picking may be improved fairly easily by proper supervision, thus facilitating a greater increase in the area of cotton. The area

TABLE II.38 SUKUMALAND: LABOR REQUIREMENTS FOR FOOD CROPS AND COTTON CASH CROP

Crop	Area	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Food Crops													
Maize	0.56	-	16	24	16	8	-	-	9	-	-	-	-
Sorghum	0.33	14	16	-	10	-	-	5	2	-	-	-	-
Groundnuts	0.12	-	9	3	-	-	-	2	2	2	3	3	-
Cowpeas	0.08	2	3	-	2	-	-	1	-	-	-	-	-
Sweet potato	0.20	5	6	2	5	2	-	-	-	-	-	-	-
Total for food crops	1.29	21	50	29	33	10	-	8	13	2	3	3	-
1. Total available man-days[a]		90	93	93	84	93	90	93	90	93	93	90	93
2. Man-days remaining for cash crop		69	43	64	51	83	90	85	77	91	90	87	93
3. Cotton — man-days/ha.[b]		17.30	39.54	24.71	17.30	17.30	-	29.65	29.65	42.01	29.65	34.59	-
4. Possible cotton area (ha.)[c]		4.00	$\boxed{1.09}$	2.59	2.95	4.80	-	2.87	2.60	2.17	3.04	2.51	-
5. Man-days for 1.09 ha. cotton	1.09	19	43	27	19	19	-	32	32	46	32	37	-
6. Total for all crops	2.38	40	93	56	52	29	-	40	45	48	35	40	-
7. Remaining days available		50	-	37	32	64	90	53	45	45	58	50	93
8. Possible additions[d] of cotton area (ha.)		2.89	-	1.50	1.85	3.70	-	1.79	1.52	$\boxed{1.07}$[e]	1.96	1.45	-

[a] Based on the number of days in each month x three labor units.

[b] From observations relevant to North and Central Sukumuland.

[c] Computation: line 2 ÷ line 3; the lowest value is the limit on cotton area which can be grown on the family farm (i.e. 1.09 hectares).

[d] Computation: line 7 ÷ line 3; the lowest value is the limit on additional cotton area (i.e. 1.07 hectares).

[e] Limit to cotton area if mechanized assistance is available to supplement labor required in December.

of cotton shown as the limit (line 8 of Table II.38) is that which the family should be able to manage in the block farm.

In the actual scheme, an area of 1.42 hectares of cotton per family was planned, based on a yield of 18.16 quintals picked as follows: (1) first picking, 50 percent of total crop @ 22.7 kg. per man-day; (2) second and third pickings, 50 percent of total crop @ 13.6 kg. per man-day. This picking rate probably is over-optimistic, and to achieve it on the cotton block may necessitate reducing the area of cotton on the family farm. This would lead to a substitution of hired engine-powered cultivation on the block for the hand-powered cultivation on the family farm. With the relative abundance of hand-labor and the scarcity of capital, such a substitution is not economically efficient even though the farmers gain extra leisure time. In this case "with present factor-cost relationships it is never worthwhile substituting capital for labor, it is only economic to supplement labor with capital".[66] Furthermore, it is important to note that:

> There is no case for the introduction of tractors in areas where ox-plowing is established, these can perform the same function as tractors more cheaply. In areas where ox-plowing is not established, however, the tractor is more useful than oxen. It is easier to train a smaller number of tractor drivers than say 5 times the number of ox-teams, nor can the ox-plow cope with five foot ridging.[67]

Tractor-hire Service: Ghana

Operation of the Service

The functions of a tractor-hire service closely parallel the Tanzanian block cultivation schemes in that engine-powered cultivation is made available to small farmers by a government-sponsored operation. The main differences lie in the organizational framework of supervision and extension services accompanying the block schemes. A true tractor-hire service offers operators and equipment to all farmers willing to hire, with or without supervision of the farmers' operations.

Mechanization services are available to farmers today in Ghana under the Mechanization and Transport Division of the Ministry of Agriculture. This service was reorganized in July, 1967 and again in July, 1968 so that it now operates out of 29 centers in 8 regions. The availability and charge for each type of service is shown in Table II.39.

In northern Ghana, targets for the mechanization service were calculated at a total of 27,592 hectares of work distributed among 15,527 farmers.[68]

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[66] Collinson, *Economics of Block Cultivation Schemes*, p. 3.

[67] *Ibid.*

[68] Work was distributed over the following operations: plowing (87%), ridging (2%), harrowing (2%), planting (2%), combine-harvesting (3%), clearing (4%).

TABLE II.39 GHANA: MECHANIZATION SERVICE CHARGES TO FARMERS

Crawler Tractors	Charge	Wheel Tractors	Charge
	\$/ha.		\$/ha.
Clearing of virgin forest	420	Plowing	10
Clearing secondary forest	270	Harrowing	5
Clearing coastal thicket	193	Ridging	10
Clearing savannah woodland	94	Intercultivation	5
Earth work/day of 8 hours	145	Planting or drilling (with or without fertilizer)	12
Clearing of bush	63	Slashing	10
		Harvesting rice/day[a]	72

Cost of Movement:

Wheel tractors - \$0.12/kilometer - one way only.
Crawler tractors - \$0.74 kilometer plus \$0.37/kilometer for return journey.

Services will be rendered only after the full cost of operations has been paid in advance.
Mechanization will be restricted to areas within a [illegible]-mile radius of these centers. (Blocks less than 2 hectares will not be accepted.)

Source: Ghana Ministry of Agriculture, Memorandum: *Cost of Tractor Operation*, Gen/T.10/SF.4/V.2/19 (Accra: Mechanization and Transport Division, 1 August, 1968).

[a]Information for 1967.

This target could be exceeded if spare parts and fuel were available to maintain tractors and machines close to their maximum operating efficiency.

Tractor-pools are equipped principally with Zetor Super-50 hp. and Bratstvo (Yugoslavian) crawler-tractors BNT-40 hp. and TG-90 hp. (Figure 2.25 and 2.26.) The Mechanization and Transport Division sets up small maintenance shops in each major area of concentration. Each district has 12 wheel tractors from Czechoslovakia and seven crawler tractors from Yugoslavia. Many of the problems faced by the MOA in operating the tractor-hire and machinery-service for Ghanaian farmers have existed ever since the equipment was first acquired. The types of problems emanate from the following: (1) machines are not the right type for tropical conditions; (2) service and maintenance personnel are not available to maintain machines; (3) tractor operators are not properly trained; (4) approximately 900 tractors are on the books but how many are not in operating condition is unknown; (5) spare parts and fuels are difficult to obtain and funds are not available to make local purchases where certain supplies are locally obtainable.

The extension service makes the preliminary survey to estimate the demand for machinery. The farmers personally contract with the Mechanization and Transport Division for Contract Plowing and must pay in advance. Basic charges are approximately $15.00 for plowing and harrowing/hectare ($10.00 for plowing only), which appear to be insufficient to cover the costs of operation. However, accurate costings have not been made. Crawlers cost the farmers more per hour and transport charges are also higher.

Some General Observations Drawn from the Ghanaian Experience

A number of general observations can be drawn from the operation of the tractor-hire service in Ghana. Although these are specifically related to one country they are germane to the general subject of operating tractor-hire services in any country.

1) Administration

Large quantities of cultivation and clearing equipment were imported into Ghana soon after Independence. Prior to the *coup d' état*, on February 24, 1966, the operation of this equipment was under the jurisdiction of the Farmers' Cooperative Council. Subsequently, the equipment and the operation became the responsibility of the Ministry of Agriculture. Under the direction of the MOA, it was arranged to operate the equipment in the field through the Crop Production Division and to maintain the equipment through the Mechanization and Transport Division. *This division of responsibilities was not practicable*, however, and toward the end of 1968 the responsibility for wheel tractors and agricultural equipment was given to the Crop Production Division and crawler tractors became the responsibility of the Mechanization and Transport Division.

Figure 2.25 Tractor and Equipment Depot (Ghana): Tractor Workshop
Many tractors are to be found throughout the country in need of spare parts, service facilities and skilled mechanics to return them to agricultural operation. (AFR-258)

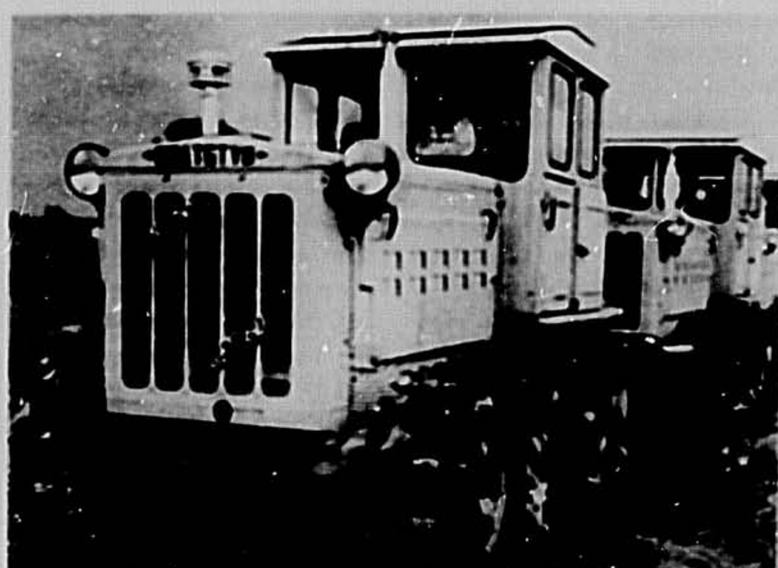

Figure 2.26 Tractor and Equipment Depot (Ghana): Crawlers
New tractors are parked in a field where they have remained since delivery. In many cases, little is required to put this equipment into working order. (AFR-264)

Thus, the direction of tractor power is still split but according to type of equipment so that individual machines do not fall to the responsibilities of two divisions of the MOA.

2) Operational Efficiency

Information from the annual report of the Mechanization and Transport Division (1 July 1967 - 31 July 1968) was not encouraging. (At that time the reorganization of the tractor-hire service was pending.) The summary of machinery and implements at each mechanization unit showed a total inventory of 420 crawler tractors and 1129 wheel tractors. Of this total figure 478 crawlers (145 declared unserviceable) and 800 wheel-tractors (333 declared unserviceable) were distributed throughout the country in the various mechanization districts. With the reorganization of the tractor hire service there arose a new spirit of determination to bring this equipment back into service. However, to do this the service needs well-trained and disciplined drivers and mechanics and must maintain the high calibre of personnel who are in executive positions.

3) Operational Costs

Actual operations of the service have been heavily subsidized. Wheel-tractor operations were subsidized up to 42 percent, charges for clearing by crawler tractor were subsidized up to 62 percent of the estimated cost.[49] However, it is impossible to determine the exact subsidy accurately without costings and inaccurate data on subsidization confuses the true financial cost of the scheme. The official costs of tractor operation for the tractor hire service are shown in Table I.7. Depreciation charges amount to one-third of total running costs in the case of crawlers and almost 23 percent for wheel tractors. This cost appears average compared with the other data. However, since depreciation is based on the number of tractor running hours, the cost of depreciation used in this estimate suggests very efficient organization which was not the case. Furthermore, depreciation charges become further confused when a large number of tractors are unserviceable. Overhead charges, amounting to 30 percent of total costs include a substantial proportion for transportation. Certainly, the cost of moving tractors is high, but it is probable that supervisory and administrative charges exceed the amount allowed in these costings.

4) Management and Supervision

There is evidence that the tractor-hire service was well received by progressive farmers who were anxious to make use of it, provided that timely service could be maintained. Apparently, the services offered were economical from the farmers' point of view. Subsidized services may be necessary, but

[49]See Tables III.25 and III.27.

of equal importance is an accurate account of the operational costs with detailed costings and close supervisory management both at the administrative level and in the field.

Tractor-hire Service: Nigeria[70]

<u>Government Service</u>

An average of 182 wheel-tractors have been imported annually from 1961 to 1967 resulting in a total 1274 tractor units. It is estimated that there are about 1,200 wheeled tractors in use in Nigeria (500 in the west, 500 in the north, and 200 in the east). Only about 400, however, are used in agriculture. Important aspects of tractor-hire service in Western Nigeria appear to be as follows:

1. Demand for tractor services is seasonal. It is limited to seed-bed preparation for a small range of crops, tied into the MOA production schemes.

2. The average output per tractor tended to be low. Costs of operating tractors exceeded MOA charges by $1.34/hour, or including depreciation, exceeded MOA charges by $2.24/hour. The Tractor-hire Units just met the direct operating-costs.

3. Farmers generally are well-satisfied with work done despite difficulty in obtaining timely service.

4. There are limited opportunities for the Tractor-hire Units and, as currently operated, tractors are unlikely to contribute significantly to the state's agricultural development.

5. The mechanization of rice production has received much attention because of the need for early planting, the difficulty of hand cultivation, the lack of traditional hand cultivation, the possibility of two crops per year which requires timely operations, and the high value as an annual crop.

6. Government departments and agencies are prime users of wheel tractors but encounter procedural difficulties in ordering and paying for spares. Consequently, many workshops are short of parts, hence tractor operation and maintenance are severe problems. The situation is aggravated by accelerated wear due to inexperienced drivers and tropic conditions.

7. The most successful Tractor-hire Units operate in rolling savannah areas well suited to mechanized farming. In these areas, the fairly light soils are easy to manage, the principal agricultural operations are tillage and cultivation of annual crops, the population density is fairly low (about 34 people per square kilometer), there is a relatively adequate supply of arable land and the minimum field size is about 1.2 hectares.

8. The average farm under mechanical cultivation is 4 hectares. Cultivation practices of the farms can be summarized as follows: 72 percent of

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[70] The factual information for this section is drawn mainly from Purvis, *op. cit.*

the farmers have only one field cultivated, up to four pieces of land are worked by some farmers, farms were an average of 20 to 25 kilometers from the Tractor-hire Unit and about 10 kilometers from the nearest road, most farmers grow single (sole) crops, the proportion of farmers growing different crops were: maize, 68 percent; tobacco, 16 percent; rice, 13 percent; and kenaf, 3 percent.

9. Farmers believed that tractors increased income, based on: larger yields (54% more on all crops), increased gross output exceeding the increase in costs (costs amounted to $20.8 per hectare), the planting season bottleneck was alleviated and labor used more efficiently.

Contracting Operations

The following points serve to indicate the gradual shift in emphasis away from government-owned tractor enterprises to private contracting enterprises.

1. The MOA, Engineering Division, has proposed that the government sell serviceable tractors to interested farmers and allow them five years to pay. This would help them begin independent farming, and allow the MOA to withdraw from an unprofitable tractor-hire business.

2. In 1966, the MOA gave a three-year loan on six tractors to private farmers. They also received a plow, a disk-harrow, a trailer and were permitted to borrow other tools from the tractor-hire service. Land was not a problem. Only one man has defaulted; the others are currently repaying the loan and using the tractors.

3. The MOA is charging $13.00/ha. for plowing while private contractors are charging $10.40/ha. for the same work.

4. The demand for services exceeds the capacity of the Tractor-hire Units of the government which only operate at about 300 hours per year. The government has good mechanics but spare parts are hard to obtain.

5. Three private operators are obtaining about 800 hours per year of custom-work with MF 165 and DB 550. Charges range from $5.20/ha. for ridging land and $10.40/ha. for plowing land near the river bottoms. Two large private farms are raising upland-rice on 1,000 hectares and cotton on 2,400 hectares. Their average use is 1,000 tractor hours/year.

Tractor-hire Service: Gambia

In 1950 the Gambian government established the Tractor Plowing Scheme for farmers and for the first three years performed the service free as a popularizing demonstration. Charges for plowing and disking then were made on a subsidy basis, and the amount of the subsidy annually decreased from $84.72/ha. in 1962 to $8.40/ha. in 1967. The present plan is to eliminate the subsidy within a few years.

Since 1962 the Tractor Plowing Scheme has been restricted to plowing

alluvial soils for rice production, because the government policy has been and continues to be self sufficiency of farmers in rice production. Furthermore, these alluvial soils are plowed when dry, for timely seeding of rice after the onset of the rains. When dry, the soils, being mostly clay loams and very firm, cannot be plowed except by tractor.

Rice production has increased from 577 metric tons (unhulled) in 1962 to 4,042 metric tons in 1967. In the same years, the area of alluvial soils plowed and disked for rice by the Tractor Plowing Scheme rose from 250 to 2,000 hectares.

Officials of the government contend that if the Tractor Plowing Scheme were greatly extended on upland soils, large-scale land clearing and continuous tillage would become widely practiced, and the results would lead to accelerated soil erosion, hardening of laterite, and creation of a "dust bowl".

The Tractor Plowing Scheme has its headquarters in Sapu, 280 kilometers up river from Bathurst in the center of the wetland rice-producing area of Gambia. Here, the soils are most suitable for wetland rice because they are less affected by salt from the ocean tides, less acid, and, after flooding, become dry quickly enough for tractor plowing.

Soils used for wetland rice production are the red clay alluvium and the black clay alluvium along the Gambia River. Both soil areas are flooded during the rainy season from June to October, and cannot be plowed until dry.

However, when dry they become very hard and can be plowed only with a tractor. (Plowing for rice is carried out mostly during March, April, and May.) *For these reasons and to encourage self sufficiency in rice production, the Tractor Plowing Scheme offers services to farmers only on wetland rice soils.*[71]

Rice growing among the Muslims (the predominant ethnic group in Gambia) has been assigned traditionally to women. Increasing rice areas, has given Muslim women more work, more income and therefore, greater independence.

At present there are 29 operable tractors used for plowing rice soils in the Tractor Plowing Scheme. The workshop and repair facilities can serve 60 tractors. Demand for tractor plowing for rice far exceeds the service available.

The area of rice soils plowed in 1967 by the Tractor Plowing Scheme was approximately 2,000 hectares and the eventual target area is 4,800 hectares. To achieve this goal, additional support to the Scheme is recommended:

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[71] Most of the upland soils used for field crop production are loams and sandy loams. Many of these soils are ground-water laterites, and the government of Gambia is encouraging the use of oxen as the primary source of power.

1. Landing crafts to transport the tractors and plows along the Gambia River. The crafts also can serve as a means of cheap, convenient transportation for distributing seeds, fertilizers, and insecticides and for the marketing of rice, groundnuts, and forestry products.

2. Mobile workshops on some of the landing craft to facilitate minor repairs.

The area plowed and disked, the subsidy per hectare, and the estimated total production of rice (unhulled) grown on the area so plowed and disked, for the years 1962 to 1967 and the break-even point (point of no subsidy) for the service are shown in Table II.40.

TABLE II.40 GAMBIA: AREA PLOWED AND DISKED, SUBSIDY AND ESTIMATED PRODUCTION IN TRACTOR PLOWING SCHEME, 1962-1967

Year	Plowed and Disked	Total Subsidy per Hectare for Plowing and Disking	Estimated Production (Unhulled Paddy Rice)
	hectares	dollars	metric tons
1962	253	34.30	578
1963	524	11.90	1153
1964	867	5.70	1970
1965	1277	7.40	2732
1966	1424	5.20	2825
1967 (estimated)[a]	2025	3.40	4042
Goal (No year indicated)	4860	-	9707

[a]In 1967, the charge to the farmers for plowing and disking rice land was $17.17 per hectare, but a charge of $22.89 per hectare was considered.

Assistance has been requested to make a soil and land-use survey to determine more areas of suitable soils for rice and the feasibility of swamp and flood control in these areas.[72]

Also, an important principle has been recognized in restricting to 0.2 hectares the amount of virgin land which a farmer can offer for cultivation. The farmer is encouraged to farm his traditional area in addition to the virgin area. After a few years of successful performance, the allowed area of new rice land will be increased to 0.9 hectares. Thus, agricultural machinery is used to improve the productivity of the land already in use as well to exploit the high fertility of virgin land.[73]

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[72]Government of Gambia, Paper AD/mech.1/8, 22 June, 1967.

[73]*Progress Report: Riceland Tractor Ploughing* (report by the Department of Agriculture and Natural Resources of Gambia, undated), p. 19.

Advanced prepayment for tractor plowing is an inflexible rule, because, "almost everyone contracts debts in the most intricate pattern to the utmost of his creditability."[74]

Tractor-hire Service: East Africa

Kenya[75]

Tractor Contract Service during 1967/68 operated 30 tractors for an average of 1,020 hours/tractor. The operation and depreciation cost was $5.14, and the contract-service charged $5.40, compared to $7.00 charged by most private contractors.

Out of a total of 30,600 hours recorded on the tractor hour-meters, 30,000 were productive, including transporting fuel and supplies, making an overall average of 77 percent productive time, despite an average of 800 to 960 kilometers per tractor annually spent on the road travelling between jobs.

Some General Conclusions Drawn from the East African Tractor-hire Services

Conclusions reached on the various East African Tractor Hire Services that were made by the IBRD[76] appear to have general applicability throughout Equatorial Africa:

1. The cost per hour of tractor operations varies inversely with the number of hours per year of tractor use. Costs are substantially lower where relatively simple cultivations are carried out on large tracts.

2. Mechanization is normally accompanied by improved farming practices which lead to increases in production although data on crop yields under mechanized cultivation are unreliable.

3. The transport of the tractor and equipment amounts to about one third of the total running hours, in both the governmental and the private sector. More intensive tractor use would help to reduce this loss of time.

4. The total cost of tractor operations in East Africa ranges from about $2.10 to $4.30 per hour. Off-season work could considerably reduce this figure.

5. The total cost per hour of government tractor operations appears to run 50 to 100 percent higher than that of privately operated tractors. This difference reflects a generally higher rate of utilization in the private sector and, particularly, much lower overhead expense.

6. Government tractor pools have had to be highly subsidized, often by more than 50 percent. It seems questionable whether the increases in output resulting from mechanization would meet the full costs of the service.

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[74] *Ibid.*, p. 21.

[75] C.M. Downing, Personal Communication, October, 1968.

[76] International Bank for Reconstruction and Development, Permanent Mission in Eastern Africa, *Agricultural Mechanization in East African Countries*, pp. 3-5.

7. There is continuing pressure from politically potent, small-scale farmers for such pools to be established or expanded. Farmers with small holdings have difficulty in obtaining the benefits of mechanization but there would seem to be considerable scope for assisting the spread of small- and medium-scale private contracting operations to provide these services.

8. More complete and reliable information on mechanization is necessary to provide a firm basis for public policy.

9. Governments seeking to mechanize agriculture should do this through small- and medium-sized private contractors.

10. Even in cases of large-scale crop production schemes consideration should be given to the advisability of engaging private contractors to supply the required mechanized services.

11. In any one country the government should encourage the use of not more than three makes or models of tractors, distributed through an appropriate network of dealerships and spare parts depots.

12. Governments should establish training programs to cover tractor driving, tractor and equipment maintenance, business management and accounting, and bookkeeping.

13. Only optimum-sized wheeled tractors should be encouraged through credit programs (i.e. those in the range of 40/60 b.h.p.).

Three conclusions reached in 1960 from the experience of the tractor-hire service in Uganda also have general application:

> 1. It is true that even for the tractor hire service the main initial troubles were mechanical and technical but in the long view mechanization is an agronomic and economic experiment and it is about these issues that data is [sic] most critically needed and it is still sadly lacking.
>
> 2. Two hundred pounds of cotton [yield per acre] cannot be mechanized.
>
> 3. Mechanization was never an end in itself.[77]

Large-scale Enterprises: Tendaho Plantations, Ethiopia

The first area of private commercial enterprise selected for study is the Tendaho Plantations Share Company (share capital of $2,472,000) which is a joint venture between agencies of the Imperial Ethiopian Government, Ethiopian share holders and Mitchell Cotts and Company (Ethiopia) Limited. The total amount invested, including long-term loans, is about $5,840,000. These plantations are located in the Danakil Desert about 380 kilometers northeast of Addis Ababa in the lower Awash Valley. The operation is being expanded gradually to the full land concession of 10,000 hectares.

The land concession is being taken up by the three plantations: Dubte,

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[77] J.L. Joy, (ed.) *Symposium on Mechanical Cultivation in Uganda* (Kampala: Makerere University College, Faculty of Agriculture, 1960), pp. 6 and 8.

Dit Bahari and Logghia; in addition, the Crown Estate at Barga is managed by the Company, and assistance is given to numerous small cotton growers through an outgrowers scheme which, in the 1966/7 season contributed approximately 30,000 quintals of raw cotton in addition to 64,000 quintals produced on 4,200 hectares of the two main plantations (Dubte and Dit Bahari).

Operation began in 1961 with a pilot scheme. In the 1962/3 season 1100 hectares were planted at Dubte. The Dit Bahari plantation was established in the 1964/5 season.

<u>The People</u>

Local inhabitants are Afars. Their mode of living is similar to the Afar of the middle Awash Settlement. However, the Tendaho operation is not concerned specifically with settlement. The work force consists mainly of local highland people, many from small farming families. These men and women are accustomed to farming and can supplement their own farm incomes with cash earned on the plantations. Some Afars also work on the settlement.

<u>Crop Production</u>

Cotton is the only cash crop produced, and in recent years Acala 1517C has been grown both at Dubte and Dit Bahari, the two principal plantations from which the bulk of production is obtained. Logghia farm has been used generally for seed production. The gradual extension of the area under cultivation, the yield estimates, and the total value of the product estimated on the basis of 36 percent lint and 62 percent seed are shown in Table II.41.

The computations in Table II.41 are based on the actual domestic prices for 1966-9, and estimated prices for the previous years. There is a ready domestic demand for cotton lint; all cotton seed, except for replanting, is exported. In 1966/7 a small quantity of lint was exported and, because of its high quality, was able to command a higher price on the world than in the domestic market. The implications of diversifying exports are of vital importance to the Ethiopian economy.

TABLE II. 41 TENDAHO PLANTATIONS: ESTIMATE OF TOTAL VALUE PRODUCT FOR PERIOD 1962/3 - 1968/9 FOR TWO MAIN PLANTATIONS

	1962/3	1963/4	1964/5	1965/6	1966/7	1967/8	1968/9
Dubte Plantation (ha.)	1100	2165	2500*	2500*	2865	3500	3500
Dit Bahari Plantation (ha.)	-	-	1500*	1500*	2000	1530	2000
Total Area (ha.)	1100	2165	4000	4000	4865	5030	5500
Yield (q./ha.)	5.6	12.0	8.0	9.7	13.6	14.3	16.5*
Total raw cotton production (quintals)	6160	25,980	32,000	38,000	66,164	71,929	90,750
Estimated raw cotton price ($/q.)	24.18	-	-	-	-	-	-
Lint							
Lint production (36%)	-	93.53	11,520	13,680	23,819	25,894	32,670
Estimated market price ($)	-	70.00[b]	70.00	70.00	72.54	72.54	72.54
Total Value	-	654,710	806,400	957,600	1,727,830	1,878,350	2,369,882
Seed							
Seed production (62%)	-	16,107	19,840	23,560	41,022	44,595	56,265
Estimated market price ($)	-	8.06	8.06	8.06	8.06	8.06	8.06
Total Value	-	129,822	159,910	189,894	330,637	359,444	453,496
Total Value Product	168,949	784,532	966,310	1,147,494	2,058,467	2,237,794	2,823,378

* Estimated

b Ginnery began operating in 1963/4 season; price based on world market for good Egyptian cotton (1963-6).

Calendar of Operations

Considerable handlabor is employed throughout the annual operations. Table II.42 shows the annual calendar and the approximate distribution of labor employment based on the 1968/9 season.

TABLE II.42 TENDAHO PLANTATIONS: CALENDAR OF OPERATIONS AND DISTRIBUTION OF LABOR EMPLOYMENT (ON 5500 HECTARES)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
				Rain (100 mm)							
final pick	.[a]gin					.second irrigation					.pick
				.disk							
				.first irrigation		.interrow cultivation					
							.third irrigation				
					.germination			.interrow cultivation			
						.weed (hand)		.thin (hand)			
						.interrow cultivation		.fourth irrigation			
									.weed		
Approx. Monthly Labor Force											
Regular											
340	340	340	340	340	340	340	340	340	340	340	340
Ginnery											
-	500	500	500	500	500	-	-	-	-	-	-
Day											
440	440	440	1440	1440	1440	1440	-	1000	2660	4660	5160
Approx. Total Labor											
1000	1500	1500	2500	2500	2500	2000	340	1340	3000	5000	5500

[a]Dot indicates the point at which the operation begins. Each operation takes about 2-4 days.

Major Inputs

The six principal direct cost items are estimated in Table II.43.

1) Tractor Operational Costs

The break-down for tractor costs is based on the cultivation field capacities currently used in preparing budgets.

2) Day Labor

Wages are the single largest cost item; the magnitude of this cost shows how large is the cash flow from the Company into the local economy. In addition to field workers there are another 500 workers employed by the ginnery more than 5 months of the year with a wage bill of about $16,250, and a permanent technical staff of over 300.

3) Water

Irrigation is essential for any commercial crop since the annual rainfall averages only 100 millimeters. Before the plantations were started, a large part of the area was flooded each year during the rise of the Awash River. A system of levees has been built to control and make effective use of this flooding to irrigate 5,000 hectares of cotton by gravity from the high flood-waters. In addition, 500 hectares are above this level and are pump-irrigated. (Figure 2.27.)

Irrigation is usually practiced four times with an occasional fifth when necessary. The length of time for each irrigation (from 10-15 days) reaches a penetration of 25 cms. on the first and fourth time, and 20 cms. on the second and third.

4) Pest Control

Timeliness of application is essential in the application of insecticides. Costs include the charge for hiring aircraft. The first spray is for Jassin white fly, using DDT and Aldrin. The second spray is for the American bollworm, using Shell Endrin.

5) Seed

Planting has been established at 30 kg./ha. after trials with 20 and 40 kg./ha.

6) Fertilizer

In the future, fertilizer will be applied to areas showing signs of nutrient depletion. The budgeted costs shown in Table II.43 can be interpreted only as one possible situation for the present organization. By comparing data in Tables II.41 with II.43, it is possible to arrive at an estimate of gross operating profit for raw cotton at the ginnery. No account has been taken of any overhead costs, which are heavy. Budgets such as the one presented here are designed merely to illustrate a possible operating situation, and bear little relationship to final profits after all obligations to the shareholders have been met.

TABLE II. 43 TENDAHO PLANTATIONS: ESTIMATED COSTS FOR MAJOR INPUTS OF THE PRODUCTION FUNCTION, 1968/9 SEASON

Computation of estimated cost of inputs for 5500 hectares		Total Cost dollars
1. **Tractor Operations**		
50 tractors @ 1400 hours = 70,000 hours @ $2.76		
a. Fuel	67,973	
b. Repairs, etc.	39,111	
c. Wages	13,322	
d. Depreciation	50,383	
e. Total running costs	170,789	
f. Overheads	22,411	193,200
2. **Day-laborers' wages**		
Estimate of total wage bill:		
a. Average wage $0.864 per day working an average of 5 days per week Feb. - Oct. @ $12.091 per month	140,493[a]	
b. Picking season average wage for 45 kg. @ $0.05/kg. Nov. - Jan. @ $18.136 per month	224,337[a]	364,830[b]
3. **Irrigation** 5500 ha. @ $6.549		36,020
4. **Pest Control**		
Cost of insecticides, application and administration ($10.00-15.00 per application including all spraying costs)		223,621
5. **Seeds**		
30 kg./ha. @ $8.06 per quintal		13,299
6. **Fertilizer**		
2 quintals/ha. @ $10.075 on 1500 ha.[c]		15,113
Total		846,083

[a]Slight error due to currency conversion.

[b]Estimated budget breakdown of wage bill:

1. Planting & cultivating	($7.254/ha.)	39,898[a]
2. Irrigating	($1.511/ha.)	8,312[a]
3. Picking	($33.249/ha.)	182,871[a]
4. Bagging	($2.015/ha.)	11,083[a]
5. Balance -- being wages for clearing, dyke repairing and miscellaneous work		124,666
Total		364,830

[c]Fertilizer only applied to medium growth soil -- 1500 ha. estimated.

Figure 2.27 Tendaho Plantation (Ethiopia): Irrigated cotton crop
Cotton block of 25 hectares growing on Dubte Plantation. This area of the lower Awash Valley is part of the Danakil Desert about 380 kilometers northeast of Addis Ababa. Annual flooding has created a very fertile soil which, with carefully controlled irrigation, now grows excellent quality cotton. The area is divided into 25 hectare blocks by levees. The block on the right, at present unused, was one of the original areas in which ridge and furrow irrigation has been practiced. Flood irrigation is now employed, being more economical on water and, in the near future, this unused field will be releveled and brought back into use. An average yield of 1430 kg./ha. was realized in the 1967/8 season and 1450 kg./ha. is anticipated for 1968/9. (A29-15)

Management

Cotton plantations of such dimensions involve a complex system of management. Both administration and management must be intensive and efficient to avoid large losses. Tendaho Plantations demonstrate capabilities of intensive and efficient management in isolated and hitherto barren country, including considerable expenditures on administration and other fixed costs. No attempt is made to cover all the inputs into the organization, but it is intended to demonstrate the main inputs into the production function and the economic ramifications of expenditure on direct costs.

Alternative crops

For the purposes of diversification maize and safflower have been suggested as alternative crops. Rice and sorghum were tried but most of the grain was destroyed by birds before it could be harvested. No effective bird control program has yet been devised.

Large-scale Enterprises: Commercial Farming in Setit-Humera, Ethiopia

The second area of private commercial farming, lies in the northwest of Ethiopia about 750 kilometers from Addis Ababa close to the Sudanese border between the Setit and Angareb Rivers. The area covers between 3,500 and 4,000 square kilometers of land which has been developed primarily by private

enterprise with the assistance of modern engine-powered equipment although a large number of ox-farmers, with small farms of six to eight hectares have settled on the area's fringes during the past 50 years.

Today the area is one of rapid, unplanned economic expansion. In 1966 there were an estimated 158 farmers using 229 tractors.[78] More recent estimates made by the Study team suggest 280 farmers owning more than 400 tractors, with 19 different models from 12 different manufacturers in 8 different countries.

Experienced and inexperienced farmers coming into the area have been able to obtain land easily. (Figure 2.28 and 2.29.) Land has been assigned by the local vice-governor to individuals for farming in blocks of 400 to 1,000 hectares. One original concession with a 70-year lease was granted for about 7,000 hectares. However, no titles have been given to the land, nor has the land been surveyed; no fences nor other boundaries exist. Annual taxes are paid by farmers to the local representatives of the Ethiopian government *en bloc* according to assumed crop productivity. For this reason, farmers become vague about crop yields and areas farmed.

The whole area is of considerable interest to the government and development agencies because of its high economic potential. Some 60,000 migrant workers come to the area annually at weeding and harvesting time. The area cannot be farmed economically on a large scale without engine-powered technology, despite the extensive employment of hand labor. Economic expansion in the area has been rapid, without organized planning or the development of infrastructure, especially in areas of administration, health and communications. Shortages also exist of labor, credit, market and storage facilities, and agricultural services.

Mechanization already plays an essential role in the agricultural system. The major problems can be solved only by understanding organization in which each farmer is a single functional unit, and by examining the system to determine how it can be improved to insure economic prosperity. *At present there is a real danger that the inadequately developed infrastructure may stifle expansion.* The economic approach to mechanization must relate to the whole farming structure rather than to machine operation in specific farm situations.

<u>The Land</u>

The soil is described as Vertisol (self-mulching, black cotton soil) containing at least 50 percent clay. No irrigation is practiced in the area despite the proximity of the Takaze River; the surrounding land is considerably

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[78] *Report of the Survey Mission on the Agricultural Development of Setit-Humera, 31 October - 3 November, 1967* (mimeographed) (Addis Ababa: Institute of Agricultural Research, December, 1967), p. 5-7.

Figure 2.28 Setit-Humera (Ethiopia): Small farmer. Farmer being interviewed operates with two pairs of oxen and grows cotton, sorghum and sesame. He hires tractors to plow his land for cotton and sorghum, plowing only sesame land with oxen. His most critical problem is to obtain the services of the tractor and plow when the time is right. He would like to buy his own tractor but cannot afford it. He does not know what area of land he farms. (AFR-348)

Figure 2.29 Setit-Humera (Ethiopia): Large farmer. Farmer being interviewed operates four tractors and probably 400-500 hectares of land; he is uncertain about the area he farms. He grows cotton, sorghum, and sesame and the operation is large enough to store much of the harvest for about six months until prices in Amhara cease to be depressed by the flow of produce during the harvest season. Nevertheless he is concerned about the low prices which he must accept for his produce. (AFR-349)

higher than the river, and irrigation pumping would be costly. The agriculture of the area depends entirely on the rainfall which is the major limiting factor. Average rainfall for the three years 1965-7 is shown in Table II.44. Rains before June and after October are agriculturally insignificant.[79] All crops are rain-fed and the area receives 500 to 700 millimeters of rainfall a year, almost all of which falls in three months and soaks into the soil because of wide deep cracks that exist (Figures 2.30 and 2.31).

The land is roughly divisible into two broad areas: 350,000 hectares of land bounded by the Takaze River, the northern branch of the Angareb River, the Sudanese border and 37° longitude east, which is entirely farmed by tractor cultivation (this area is approximately 600 meters in elevation; 175,000 hectares are already farmed and 52,500 are potentially useful); and 150,000 hectares lying south of the north branch of the Angareb River, bounded by the Sudanese border and 37° longitude east are, except for one farm, entirely cultivated by oxen (this area lies between 600 and 1000 meters in elevation; less than 1 percent is farmed and there are 30,000 hectares of useful farmland).

Crop Production

In the current season the average farmer cultivates 800 hectares of land, approximately 45 percent grain sorghum, 30 percent sesame, and 25 percent cotton. The price of grain sorghum in Asmara fell substantially during the 1968/9 season, and this trend in prices is probably reflected in a reduction of grain sorghum proportions from the proportions observed by the Institute of Agricultural Research in the previous season; crop distributions were then: 55 percent grain sorghum, 16 percent sesame and 29 percent cotton. The principal operations and their calendar are set out in Table II.44.

TABLE II.44 SETIT-HUMERA: CROP OPERATIONS, SEED RATE, ESTIMATED YIELD AND MEAN MONTHLY RAINFALL

<table>
<tr><th>Crop</th><th colspan="2">Cultivation Period</th><th colspan="2">Planting Period</th><th colspan="2">Harvesting</th><th>Est. Seed Rate</th><th>Seed Cost</th><th>Yield Range</th></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td>kg./ha.</td><td>$/q.</td><td>q./ha.</td></tr>
<tr><td>Sesame</td><td colspan="2" rowspan="3">early mid-June for all disking</td><td colspan="2">June-July</td><td colspan="2">Sept.-Nov.</td><td>3</td><td>18.14</td><td>3-8</td></tr>
<tr><td>Cotton</td><td colspan="2">end June-end July</td><td colspan="2">Dec.-Feb.</td><td>10</td><td>14.11</td><td>3-8</td></tr>
<tr><td>Grain sorghum</td><td colspan="2">July-Sept.</td><td colspan="2">Dec.-April</td><td>5</td><td>8.06</td><td>10-20</td></tr>
<tr><td rowspan="2">Mean monthly rainfall 1965-7 (mm.)</td><td>Apr.</td><td>May</td><td>June</td><td>July</td><td>Aug.</td><td>Sept.</td><td>Oct.</td><td>Nov.</td><td>Total</td></tr>
<tr><td>6.67</td><td>15.00</td><td>87.75</td><td>148.92</td><td>210.83</td><td>70.83</td><td>50.83</td><td>0.50</td><td>591.33</td></tr>
</table>

[79] *Ibid.*, p. 9.

Figure 2.30 Setit-Humera (Ethiopia): Cracking black clay soil The area receives 500 to 700 mm. of annual rainfall, almost all of which falls in the three month period mid-June to mid-September. The rain soaks into the soil rapidly because of the deep cracks which form during the dry season. The Vertisol is supporting a fair crop of cotton. (Cotton occupies about 25 percent of the approximately 170,000 hectares under cultivation.) (AFR-1*)

Figure 2.31 Setit-Humera (Ethiopia): Rain-fed cotton crop General view of the cotton crop growing on the soil illustrated in Figure 2.30. The crop is fair for a rain-fed area with a relatively low annual precipitation. Yield estimates of 309 kilograms per hectare are average and bear no comparison either in quantity or quality of staple to the irrigated crops of either Tendaho Plantations or Amibara Plains. (AFR-12)

Cultivation Practices

Economic resources have been moved rapidly into the area for mechanized production of three main crops. Usually each farmer grows all three crops each year. No rigid pattern of rotation is followed; when an area becomes weedy, sorghum is planted in the following season; fallow cultivation is not practiced.

Tillage practices are mechanized and the same for all three crops. As soon as the soil is moist and the weeds are sprouting (early-mid June) a one-way-level disk (24-30 disks) is pulled over the field penetrating the soil no more than 8 cms. Deeper tillage is not required because the self-mulching characteristic of the soil produces a good natural tilth. This operation may be followed after one or two weeks by a second disking if more weeds appear. Each disking is carried out at a speed to cover two to three hectares per hour.

Seed is still broadcast by hand. Sesame is sown as soon as possible after the rains, usually early in June. This assures ripening during a relatively mild time before extremes of high temperature and low humidity can cause sudden shattering of the pods. Also the early harvest provides ready cash to meet indebtedness. Cotton is planted immediately after sesame; mid-July is considered the safest date. Sorghum is sown last.

After hand-sowing, mechanized cultivation for weed control is not possible. All weeding is done with a hand-hoe and harvesting with a sickle.

The area is suitable for grain sorghum but the varieties grown are tall African types unsuitable for combining. Some sesame cutters have been observed in the area but the main problem with this crop is shattering, so harvesting is almost entirely by hand.

Sesame is harvested into small sheaves, four of which are stooked together, with 100 stooks forming a *killa* which forms the basis of payment to harvesters ($0.81 - 2.02 per *killa* depending on the relative bargaining power of farmer and harvesters). Harvesters are well aware of the critical time factor and press for high rates of payment to harvest sesame. Cotton is picked at least twice and occasionally 3 or 4 times. Cotton plants are later pulled by hand and burned. Sorghum heads are cut off with a sickle and the stalks later cut, heaped and burned.

Weeds were considered by the farmers to be the major problem of cultivation.[80] The current build-up of insect pests is becoming a more serious problem necessitating aerial spray-services. Local concern has been expressed that unless an efficient spray service can be obtained, cotton production will disappear from the area. In addition to insect damage of the field, storage

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[80] *Report of the Survey Mission on the Agricultural Development of Setit-Humera*, 31 October - 3 November, 1967, pp. 26-7.

of sesame is hazardous because of the sesame seed bug.

Costs of Production

A genuine farm management study is needed to make accurate estimates of farm costs and incomes. In the area only rough approximations have been available.[81] These are set out in Table II.45.

Major marketing is in Asmara; about 20 percent of sorghum is sold locally. Since there is no local marketing organization, most farmers are obliged to sell their crops through merchants in Humera, although the bigger farmers are able to sell in Asmara. From the information in Table II.45 it is clear that transportation and handling charges are high in relation to other costs. Without a bridge, double handling is required for truck transport to Asmara, and poor roads in the farming area necessitate haulage by tractor and trailer to the collecting points where the trucks are loaded. (Figure 2.32.)

The production of sorghum in the area has been sufficient to cause a dramatic fall in sorghum prices in Asmara.[82] The amount of sorghum exported from the area is considered equivalent to the food needs of 400,000 to 500,000 people and the Setit-Humera area is close to the northern highlands where a food scarcity exists. The possibility of a local supply of low priced grain sorghum should prove a substantial economic stimulus to the development of surrounding areas especially in the northern highlands.[83] Thus, development in the Setit-Humera area must concentrate on exploiting potential economies of scale in production by increasing crop yields, and reducing handling and transport charges, so that the falling grain sorghum price still leaves the farmer with an adequate margin above his total production costs.

Total Current Production

Using the foregoing data an estimate can be made of the approximate current levels of production from the entire area based on present cultivation practices. Such an estimate is shown in Table II.46.

Obvious economic deficiencies in the area contribute substantially to inadequate economies of scale. Any future development of this area must depend on the establishment of adequate infrastructure so that individual entrepreneurs can use their skills to exploit the potential economies of large-scale mechanized farming.

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[81] *Ibid.*, pp. 35-40.

[82] *Ibid.*, p. 34.

[83] *Ibid.*

TABLE II. 45 SETIT-HUMERA: ESTIMATED COSTS OF PRODUCTION FOR SESAME, COTTON AND SORGHUM FOR AVERAGE FARM OF 800 HECTARES

Item	Sesame	Cotton	Sorghum
	- - - dollars per hectare - - - -		
Interest on capital for operation of 800 ha. ($16,124 @ 8%)	1.61	1.61	1.61
Clearing, $26.20 per ha. prorated over 5 years	5.24	5.24	5.24
2-3 diskings at $4.03 per ha.	10.08	10.08	10.08
Seed: (seeds rates & costs in Table II.44)	.45	1.13	0.41
Broadcast seeding	2.02	2.02	2.01
Weeding	(2x)16.12	(4x)32.24	(1x)8.06
Harvesting	28.21	12.09	12.09
Total Production Costs per ha.	63.73	64.41	39.50
Estimated yield per hectare	5q/ha.	3q./ha.	15q./ha.
Cost of Production per quintal	12.74	21.47	2.63
Transport and handling charges to market	2.88	2.72	2.42
	Sesame	Cotton	Sorghum
Sacks	.63	.29	.63
Local transport	.14	.14	.14
River crossing	.40	.40	.10
To Asmara (market)	1.61	1.81	1.41
Labor	.10	.08	.10
	2.88	2.72	2.42
Total costs to Asmara	15.62	24.19	5.05
Estimated seasonal average prices (Asmara, 1967)	20.15	24.99	4.84
Margin/quintal on average price	+ 4.53	0.80	- 0.21
Average farmers area of crops	240 ha. (30%)	200 ha. (25%)	360 ha. (45%)
Average farmers total production	1200 q.	600 q.	5400 q.
Net Total Income	+ $5436	+ $480	- $1134
Net Income per hectare	+ $2.27	+ $2.40	- $3.15
Total Income for 3 crops	$4782		
Total Income for 3 crops (per ha.)	$5.98		

TABLE II. 46 SETIT-HUMERA: ESTIMATED TOTAL EX-FARM INCOME AND PRODUCTION COSTS

Crop	% of Crop area	Total area	Esti-mated Yield	Total Produc-tion	Estimated seasonal price at Asmara 1967	Estimated Transport and hand-ling costs to Asmara	Estimated ex-farm prices	Total value product ex-farm	Esti-mated produc-tion costs	Total Produc-tion costs	Estimated net Income
Units	%	1000 h.a.	q./ha.	1000 metric tons	$/q.	$/q.	$/q.	million dollars	$/q.	million dollars	million dollars
Sesame	30	51.0	5	25.50	20.15	2.88	17.27	4.40	12.74	3.25	+ 1.15
Cotton	25	42.5	3	12.75	24.99	2.72	22.27	2.84	21.47	2.74	+ 0.10
Grain Sorghum	45	76.5	15	114.75	4.84	2.42	2.42	2.78	2.63	3.02	- 0.24
	100	170.0		153.00				10.02		9.01	1.01

Figure 2.32 Setit-Humera (Ethiopia): Grain sorghum awaiting transport to Asmara The absence of a bridge over the Tekaze River necessitates the double or triple handling of all produce harvested to the south of the river. At harvest time sacks of grain are stored in every available compound in the town of Humera (on South bank) and Om Hager (on North bank) awaiting transportation. Some interest has been shown recently in building a new bridge or completing the unfinished bridge which can be seen in the upper right-side of the picture. The principal entrepreneur in the area insists, however, that more important than roads and bridges are problems of crop protection and improvement; the prosperity of the area should be insured before the costly infrastructure of market communications is installed. (AFB-350)

Large-scale Enterprises: Motoragri, Ivory Coast

Establishment of Motoragri

With the primary objective of diversifying its agriculture, the Ministry of Agriculture of the Ivory Coast initiated, in April 1965, a detailed study aimed at rapid agricultural development. Agriculture of the Ivory Coast has been dependent on coffee and cocoa; the intention is to diversify toward pineapple, teak lumber, vegetables, oil palm, cotton, rubber, rice, sugarcane and tobacco.

As a result of the intensive study, the governments of the Ivory Coast and Israel in cooperation with the private cooperative society in Israel, Agridev, signed an agreement to supply certain equipment and technicians, and to train Ivoirians eventually to operate the development activity. The Decree No. 66 - 55 was signed on March 8, 1966, and an autonomous branch of the Israeli Agridev began in the following month under the Ivoirian name of Motoragri. All costs were to be paid by the government of Ivory Coast to the government of Israel and thence to the private cooperative society

Work of Motoragri consists of clearing and subsoiling land for farming, seeding and fertilizing, constructing earthen dams, constructing secondary roads, clearing new village sites.[84] (Figures 2.33 and 2.34.) Motoragri was originally established with expatriate management. The estimated time required for Ivoirians to take full responsibilities of Motoragri, on a phased withdrawal by Israeli expatriates, appears as Table II.47.

No soil and land-use surveys had been made previously to determine the suitability of the land for each priority crop *before* trees were felled. However, in October, 1967, the government of the Ivory Coast established a logistics bureau for the scientific promotion of agricultural machinery, and a coordinating committee for agricultural machinery. Actions by the bureau and coordinating committee have included assignment of soil surveyors to make soil and land-use surveys on areas *proposed to be cleared* for planting specific priority crops.

<u>General Organization</u>

The Motoragri central station and headquarters at Abidjan consists of The Director-General's office and six major departments: Director of Works, Technical, Financial, Engineering, Training and Manpower, Supply and Transportation. (For more detailed information see Chapter V.)

The major workshop, parts depot, training school and equipment yard are located at headquarters. In addition, there are six regional stations each equipped with its own workshop, and supervised by a Israeli chief manager and a machinery specialist.

<u>Management and Supervision</u>

Very tight control is exercised on all operations by careful record-keeping and the mobility of the managers. Rapid communication is facilitated by a country-wide short wave radio network.

Motoragri appears to be successful because of thorough planning and careful follow-up on all completed jobs. Plans are made six months to one year in advance, work is carefully scheduled, and support is provided; field reports are made every ten days. However, ultimate judgment of success cannot be made until the phased withdrawal of Israelis is complete.

<u>Selection and Maintenance of Equipment</u>

Motoragri is equipped with 226 tractors, 64 cars and 7 trucks purchased

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[84] Less than 10 percent of suitable agricultural soils are used for agriculture, thus, clearing land appears to offer great scope for increasing the area of priority crops.

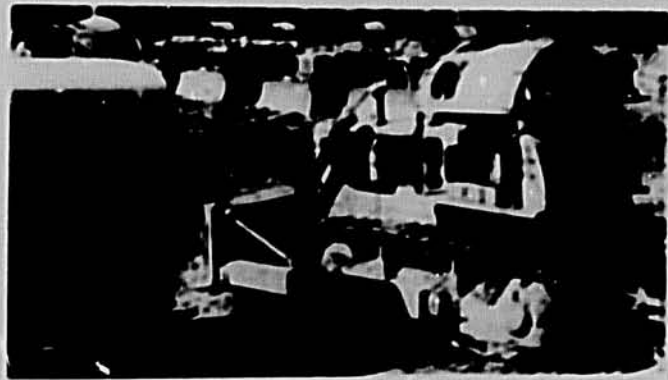

Figure 2.33 Motogri (Ivory Coast): Bulldozers in a mobile field workshop 85 percent of heavy crawler equipment is maintained in operational order by close management and rapid repair and servicing. Bulldozers such as the ones illustrated receive routine servicing and repairs, except for major work, in temporary field workshops set up close to the work site. (AFR-284)

Figure 2.34 Motogri (Ivory Coast): Teak plantation Young teak trees (9 months - 1 year old) planted in a clearing of tropical forest. The huge indigenous trees are felled and windrowed by crawler bulldozers and the teak trees set in the clearing from nurseries. Teak will make lumber for 40 years with thinnings removed every five years. The indigenous tropical rain forest is seen in the center background of the picture. Only the most suitable land is cleared for commercial production. (AFR-287)

TABLE II. 47 IVORY COAST: ESTIMATE OF EXPATRIATE AND LOCAL NATIONAL PERSONNEL REQUIRED TO ESTABLISH AN OPERATION OF 100 TRACTORS OVER A 10-YEAR PERIOD*

Location	Total Number of Technical Persons																			
	Expatriates										Local Nationals									
	YEAR										YEAR									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Country Headquarters	10	12	8	8	6	6	4	4	2	0	100	80	75	75	75	75	75	75	75	75
Regional Divisions																				
No. 1	3	3	2	2	1	1	1	1	1	0	65	60	55	55	55	55	55	55	55	55
No. 2	3	3	2	2	1	1	1	1	1	0	65	60	55	55	55	55	55	55	55	55
No. 3	3	3	2	2	1	1	1	1	1	0	65	60	55	55	55	55	55	55	55	55
No. 4	3	3	2	2	1	1	1	1	1	0	65	60	55	55	55	55	55	55	55	55
No. 5	3	3	2	2	1	1	1	1	1	0	65	60	55	55	55	55	55	55	55	55
No. 6	3	3	2	2	1	1	1	1	1	0	65	60	55	55	55	55	55	55	55	55
No. 7	3	3	2	2	1	1	1	1	1	0	65	60	55	55	55	55	55	55	55	55
Total	31	31	22	22	13	13	11	11	9	0	555	500	460	460	465	460	460	460	460	460

* Based upon estimates made by M. Lazar, Chief of the Southern Division, Motoragri, Ivory Coast, during the period 1966-1968. The estimates of manpower were made under the assumption that 100 tractors would require 2/3 of the staff as did the actual 240 tractors operated by Motoragri. (The total area of the Ivory Coast is 124,503 square miles).

by the Ivoirian government. The tractors purchased with a U.S. loan include:

1. 132 crawler tractors (half Caterpillar: D4's, D6's, D7's and D8's, and half International: TD-9's, TD-15's and TD-25's) for heavy landclearing and cultivation plus associated equipment such as dozer blades, root rakes, tree pushers, rollers, packers, scrapers and auxiliary equipment.

2. 72 Massey-Ferguson Wheel-Tractors: 48 Model 135's; and 24 Model 165's for the tractor-hire service.

3. 22 small Renault B-73 wheel-tractors for carrying laborers and implements.

4. 400 pieces of small implements such as plows, harrows, disks, planters, and trailers.

Motoragri can keep 85 percent of the tractors operational. Some temporary repairs are done in the field, and 80 to 85 percent of the spare parts are quickly obtainable. About 30 percent of major repairs are made in the central station workshop. These repairs include: re-bushing crawler tracks, over-hauling engines and transmissions, and other major breakdowns. Each region has a workshop in which most repairs and maintenance can be handled. Mobile field workshops are dispatched from the main workshop to handle work for special projects at distant locations. Orders for parts are filled by truck delivery according to three categories: weekly, monthly, and emergency. Some small frequently used parts, are also manufactured at the main workshop. The parts stock (approximate value: $404,000) represents 10 percent of the total investment in tractors and equipment (approximate value: $4,000,000).

Operation of a Regional Station

The east-central headquarters is located at Yamoussoukro, under M.B. Arazi, chief Israeli supervisor. Each region has two Israeli technicians (a chief supervisor and a mechanical expert) in charge of all work and equipment; local people are hired and trained as needed.

Each June, detailed plans are drawn up and, by August, the books are closed to all new work except emergencies. The work plan is submitted to the national headquarters in Abidjan for approval after cost estimates are made and accepted under the following procedure: 1) A client or farmer makes a request to the local agricultural extension advisor or district agricultural head, 2) if approved, the request is sent by the district head to the regional agricultural officer, 3) he in turn approves and submits it to the Ministry of Agriculture headquarters at Abidjan, 4) if the Ministry of Agriculture approves the request, it is submitted to Motoragri headquarters for consideration, 5) Motoragri reviews the request; and, if it is feasible, the request is submitted to the Motoragri regional headquarters for cost and work estimates, 6) Motoragri regional chief makes an on-the-spot survey of the work and submits the bid-cost back to Abidjan and to the original requestor, 7) if the client approves the estimated cost, the work is scheduled by Motoragri and fitted into their

time-table of operations.

Selected Institutions Related to Engine-powered Agriculture

The Agricultural Machinery Co-ordinating Unit of EAAFRO is not a research division; nor is agricultural engineering research carried out by the East African Common Services Organization (EACSO). From 1956 to 1962, there was a unit operated on an interterritorial basis. This was the East African Tractor and Implementing Testing Unit which was financed half by the British government and the other half shared equally by the three East African governments. S.D. Minto was officer-in-charge of this Unit based at Nakuru, Kenya, but worked over the whole of East Africa, testing and comparing, tractors, and implements, and conducting agricultural engineering research. The unit was very closely linked with the National Institute of Agricultural Engineering (NIAE) in the United Kingdom. All reports were published through the NIAE.

Because of a failure to agree on methods of finance and the desire of each East African country to expand its own agricultural machinery organization, this unit was disbanded in 1962. The officer-in-charge became agricultural machinery co-ordinator for East Africa under EACSO with an office at Muguga and hence attached to EAAFRO.

The Co-ordinator's duties are:

1. To be the East African link with agricultural machinery research and testing stations throughout the world and keep the three East African Governments informed on matters of interest;

2. To co-ordinate the research and investigational work on agricultural engineering being carried out in East Africa so as to avoid duplication, and try to achieve the maximum results from very limited staff;

3. To keep all three East African Governments informed of progress within each country;

4. To arrange, where necessary, inter-country co-operation;

5. To organize specialists' meetings;

6. When necessary, to arrange advisory services;

7. To maintain contact with commercial firms, teaching establishments and statutory boards on matters concerning agricultural machinery.

Research and investigational studies being undertaken within East Africa at present cover the use of hand tools, ox-drawn equipment, tractors of various sizes, numerous other implements, artificial crop driers and decorticators, crop processing cultivation techniques. However, much of the research now is done by educational establishments such as Makerere University College, Kampala, Uganda; and Egerton College, Njoro, Kenya; and the government staff concentrates on mechanization problems, settlement schemes, development projects and the heavy importation of tractors for government use.

The Functions of the Kenya Agricultural Machinery Unit[85]

The introduction of machinery into a developing country does little in itself to increase yields without knowledge of (a) its correct application (b) the timeliness of operations and (c) its suitability. To acquire more knowledge on these factors are the main aims of the Kenya Agricultural Machinery Unit. To achieve these objectives the Unit carries out tests on farm machinery and tractors and simultaneously adopts a practice of research through testing.

The submission of machines for testing is voluntary on the part of the manufacturer or his agent. No restrictions are placed on the sale of a machine, nor is any particular machine recommended or approved in the sense that it has passed some accepted rating. The most important part of a test is that carried out under farm conditions. From this testing the manufacturer receives an unbiased report on the machine's performance. At the same time the test team gains experience with the machine on how best to employ it, and information of this nature can be passed on to extension workers for the benefit of farmers and training centers because they cannot possibly be expected to have had first-hand practical experience with all machines which are used in the country. In most cases the object of the test is to determine the following features of the machine under a range of practical working conditions: (1) rate of work, (2) quality of work, (3) power requirement, (4) labor requirement, (5) handling characteristics, and (6) construction.

The British Society for Research in Agricultural Engineering

The following are excerpts from regulations adopted by the National Institute of Agricultural Engineering (Silsoe, England), in cooperation with the Government of Kenya. They were effective for testing agricultural machinery from 1956 to 1962:

1. The East African Tractor and Implement Testing Unit (EATITU) is prepared to test agricultural machines of appliances that are in, or ready for, commercial production; and to assist manufacturers in the development of agricultural machinery.

2. Tests are carried out on request.

3. Acceptance of applications for tests is normally at the discretion of the Director of the NIAE and is always subject to the agreement of the entrant to the Testing Regulations.

4. Program of tests and their location are agreed with the entrant before the start of the test. Deviations from the original program may be made in the test procedure by mutual agreement.

---

[85] Contributed by S.W. Cooper, Officer in Charge, Agricultural Machinery Unit, Nakuru, Kenya.

5. An estimate of the expenses payable by the entrant is agreed with the entrant before the work starts and will not be exceeded without the agreement of the entrant.

6. A report will be sent to the entrant at the conclusion of the test; the results of the test shall not be published without the written consent of the entrant.

7. If the entrant is agreeable to publication, the results of the test will usually be published by the NIAE. Modifications and suggested improvements may be added to the report by the entrant in the form of footnotes.

8. Full and abridged reports are to be published.

9. Provided that the results have been published by the NIAE, the entrant may use the results of the test commercially in any or all of three ways: he may distribute the full and abridged versions of the report without alteration or omission; he may quote extracts from the full report provided that the written approval of the Director of the NIAE has been obtained to the use of the extracts in their contexts; or he may mention in an advertisement that the machine or appliance has been tested (but may not suggest approval) by the EATITU.

10. In any event of any breach by the entrant of the conditions stated in Paragraph 9, the NIAE reserves the right to publish the results of the test in full.

11. Neither the NIAE, the EATITU, nor any person or body engaged on their behalf for the purpose of the test, shall be held responsible for any damage whatsoever to the machine under test.

12. A test shall not be undertaken on any machine or appliance that is intended to be the subject of an application for patent protection until the application has been properly submitted.

13. a. Separate patents may be taken out to protect subject matter discovered during the course of tests made by NIAE or EATITU.

b. If the patents taken out under the above circumstances constitute patents of addition, the manufacturer of the machine may be granted: (1) free non-transferable licences, and (2) authority to use the results elsewhere.

14. Transport charges involved in the test shall be borne by the entrant or his agent.

15. Interpretation of these regulations shall rest finally with the Director of the NIAE.

Laterite Soils and Their Management in Relation to Mechanization

Properties of Laterite

Laterite is a highly weathered material rich in secondary oxides of iron, aluminum, or both. It is nearly void of bases and primary silicates, but it may contain large amounts of quartz and kaolinite. It is either hard or capable of hardening on exposure to successive wetting and drying. True laterite interferes with land use in Africa, India, and elsewhere in the Tropics.[86]

Between 1800 and 1801, Buchanan, a British geologist and soil scientist, studied soils in southwestern India, now within the states of Mysore and Kerala. He described laterite soil:

> It is full of cavities and pores, and contains a very large quantity of iron in the form of red and yellow ochres. In the mass, *while excluded from the air*, it is so soft that any iron instrument readily cuts it, and it is dug into square masses with a pick-axe and immediately cut into the shape wanted with a trowel or large knife. *It very soon after becomes as hard as brick*, and resists the air and water much better than any bricks that I have seen in India.[87]

Laterite soils continue to harden upon exposure and to be used in India today as sources of building stones and bricks, as recently described:

> If the formation is massive and if the moisture conditions and consistency are satisfactory, laterite may be quarried and cut into blocks of the size of large bricks and on *exposure dehydrate and become as hard as granite*.[88]

S.V. Govinda Rajan[89] says the hardening of laterite soils is as follows:

> In regard to reclamation (softening of hardened laterite by flood irrigation) no research or demonstration work has been conducted. As indicated in my earlier letter, laterites if they become indurated and hard, they become irreversibly indurated.

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[86] Lyle T. Alexander and John G. Cady, *Genesis and Hardening of Laterite in Soils*, Technical Bulletin No. 1282 (Washington, D. C.: U. S. Department of Agriculture, 1962), p. 1.

[87] J.A. Prescott, and R.L. Pendleton, *Laterite and Lateritic Soils*, Technical Communication No. 47, Commonwealth Bureau of Soil Science (Farnham Royal, England: Commonwealth Agricultural Bureaux, 1966), p. 1.

[88] R.V. Tamhane, D.P. Motiramani, and Y.P. Bali in collaboration with Roy L. Donahue, *Soils: Their Chemistry and Fertility in Tropical Asia* (New Delhi: Prentice-Hall, 1964), p. 403.

[89] Dr. S.V. Govinda Rajan, Head, Division of Soil Survey and Land Use, Indian Agricultural Research Institute, New Delhi, India.

Once they become hardened, laterites do not soften with any amount of wetting. It is only soft laterite which can be softened into a puddled condition.[90]

Laterite soils have been mapped on 25 million hectares in central and southern India, where they have been farmed successfully for several thousand years. Although crop yields on laterite soils in India are low, the Indian farmers have learned a "survival" type of agriculture, this experience can help African farmers on similar laterite soils where agriculture is much younger.

The Indian farmer uses oxen power primarily. No large areas are cleared. Other soils and crop management practices on laterite soils have been described:

> The common practice of farmers on laterite and lateritic soils growing paddy [wetland rice] is to apply organic matter and green leaf as manures wherever available . . . I think that one of the beneficial effects of the addition of green leaf manure and organic matter is to prevent hardening of laterite.[91]
>
> Wetland rice will create hydromorphic conditions which may lead to the formation of groundwater laterite which is more hydrated and softer than ordinary laterite.[92]
>
> Laterite produces a number of good crops, particularly rice. Amongst other crops, mention may be made of plantation crops like coffee and tea in the hills and fruit crops like pineapples, bananas, etc. Tapioca [cassava] is also grown extensively on laterite soils . . . Shifting cultivation will lead to loss of top soil by erosion and exposure of the laterite . . . which will lead to hardening . . . due to dehydration of the iron and aluminum oxides.[93]

Laterite and Its Hardening

> Another prominent group of soils in the wet-dry tropics have been called Ground-Water Laterites. These do contain laterite or hardened relics of it as an essential feature. Although the total area of Ground-Water Laterite soils in the world is not large, they do occur as components of soil patterns in some highly populated places. The cultivators of South India learned more than a thousand years ago that they could be used indefinitely under mixed cultures not requiring regular exposure to the sun and rain. *But if the surface of Ground-Water Laterite is exposed, the doughy laterite beneath hardens and the soils are nearly ruined for crop use for a long, long time.*

---

[90] Personal communication, Govinda Rajan/Donahue, dated July 31, 1967.

[91] Personal communication dated July 24, 1968, Raychaudhuri/Donahue. (Dr. S.P. Raychaudhuri, Senior Specialist (Land Resources), Planning Commission, New Delhi).

[92] Personal communication, Raychaudhuri/Donahue, dated June 24, 1968.

[93] *Ibid.*

> Erosion tends to reduce the depth of surface soil and thus hastens the drying process. The hardened laterite is highly resistant to weathering.[94]

The Widespread Occurrence of Laterite Soils

Laterites have also been reported extensively throughout tropical and semi-tropical countries. In 30[95] countries in Africa laterites and associated soils are estimated to occupy 5,338,000 square kilometers, 18 percent of the total land surface of Africa, and after desert soils, they are the most extensive body of soils in Africa. (Figure 2.35.)

Characteristics of Laterite Soils

As identified and mapped in the field, laterites consists of at least two materials of contrasting chronological age, first described by Oldham in 1893[96] as high-level, and low-level. The high-level form of laterite occurs as hardened ironstone caps, usually of a meter of more in thickness, and appearing as erosion-resistant surface of hilltops, with edges consisting of broken chunks of laterite that have rolled or slid down the slope. Low-level laterite that has hardened on exposure usually is indistinguishable from the high-level form except that low-level laterite occurs as hardened secondary ironstone at the surface or as softer material at variable depths below the surface. In general, the deeper the laterite layer the softer it is; however, even the softest and deepest material will harden irreversibly when exposed to the air.

Most authorities agree, that both high-level and the low-level kinds of laterite are formed in low-lying areas where seepage waters moved soluble iron to concentrate at ground-water level in what is now called the laterite layer. High-level laterite was subsequently uplifted, the surface soil eroded, the secondary ironstone layer hardened, and the hardened laterite has persisted because of its resistance to weathering and erosion. By contrast, the low-level laterite is presumed to be continuously forming.

---

[94] Charles E. Kellogg, "World Food Needs and Production -- Present and Future," National Academy of Sciences, National Research Council, *Proceedings, Fourteenth Annual Meeting and Minutes of the Business Session* (Washington, D.C., October 18-19, 1965), p. 137. (Italics added.)

[95] Angola, Botswana, Burundi, Cameroon, Central African Republic, Congo (Brazzaville), Congo (Kinshasa), Gabon, Ghana, Guinea, Ivory Coast, Kenya, Liberia, Malawi, Malagasy Republic, Mali, Mozambique, Nigeria, Portuguese Guinea, Republic of South Africa, Rhodesia, Rwanda, Senegal, Sierra Leone, Swaziland, Tanzania, Togo, Uganda, Upper Volta, and Zambia.

[96] R.D. Oldham, *A Manual of Geology in India*, Chapter 15, "Laterite" quoted in Prescott and Pendleton, *op. cit.*, p. 8.

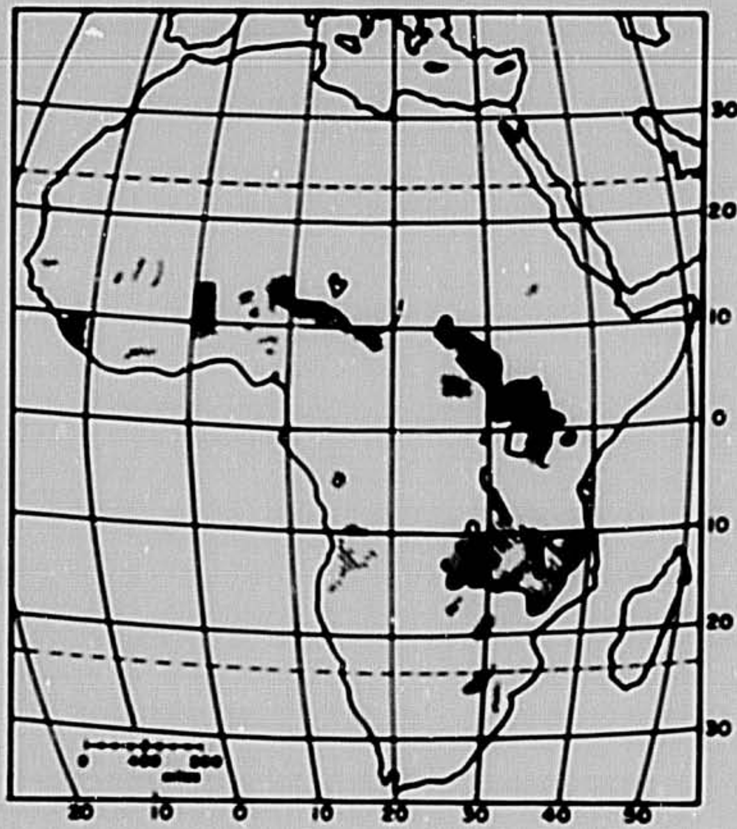

Figure 2.35 __The distribution of laterite soil in Africa__ Laterites and associated soils are estimated to occupy 18 percent of the total land surface of Africa and have been identified in 30 different African countries. They are the most extensive body of soils in Africa after desert soils. Laterites are very infertile and tend to harden on exposure. Source: Prescott and Pendleton, *op. cit.*, p. 17. (AFB-535)

Kellogg and his staff have suggested that the term laterite should be confined to ferruginous materials that harden on exposure and to relics of such materials, occurring as any of:

1. Soft mottled clays that change irreversibly to hardpans and crusts when exposed.
2. Cellular and mottled hardpans and crusts.
3. Concretions, not consolidated.
4. Concretions, consolidated.[97]

A more recent classification by Kellogg and his staff has placed laterites and latosols in Order No. 9, OXYSOLS, and most of the laterites in suborder AQUOX.[98]

Scaetta (1938-1940) described the formation and extent of laterite formation in Guinea and "*attributed the formation of hard lateritic crusts in part to the activity of man in clearing forests and exposing the surface of the soil to altered conditions.*"[99]

Laterites occur on old land surfaces under conditions of forest or forest-grass vegetation with approximately 1000 millimeters or more of annual rainfall and a definite dry season; and are formed in place on the intermittent water table by the precipitation of iron from iron-laden acid solutions on many kinds of rocks and parent materials. Laterites form more slowly on recent alluvium, young volcanic ash, calcareous soil materials and deep and slowly permeable clay soils.

The secondary ironstone in low-level laterite may occur on the surface or to a depth of three meters, and vary from a thickness of a few centimeters to two meters. The ironstone layer of both the low-level and high-level forms may be pisolitic (composed of pea-sized particles either consolidated or unconsolidated) or vesicular (with cavities and consolidated).[100] Some authorities believe that the close resemblance in structures of termite mounds and vesicular laterite is due to the latter being hardened termite-worked soil material.

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[97] Charles E. Kellogg, *Preliminary Suggestions for the Classification and Nomenclature of Great Soil Groups in Tropical and Equatorial Regions*, Technical Communication No. 46 (Farnham Royal, England: Bureau of Soil Science, 1949), pp. 76-85.

[98] U.S. Department of Agriculture, *Supplement to Soil Classification System [7th Approximation]* (Washington, D.C.: Soil Conservation Service, March 1967).

[99] Cited by Prescott, and Pendleton, *op. cit.*, p. 15. (Italics added.)

[100] Vesicular laterite resembles a coal cinder and volcanic lava and is sometimes confused with the latter.

Chemically, soft and hardened laterite consists of materials of varying proportions of hydrated oxides of iron with lesser amounts of alumina and silica. The primary difference between soft and hardened laterite is the amorphous nature of the former and the crystallinity of the latter.

Laterite soils are usually highly leached, strongly acid, with a low level of fertility. Nitrogen is considered the first nutrient element to limit plant growth. Phosphorus usually is rendered unavailable because of the high fixation as iron phosphate. Availability of zinc, molybdenum and copper is also low. Furthermore, the hardened ironstone layer restricts root elongation, decreases available water for plant growth during dry periods and is conducive to an excess of water for plant growth during the rainy season. For these and other reasons, a satisfactory response is seldom obtained with the use of fertilizers on most field crops growing on laterite soils. (Figures 2.36, 2.37, 2.38 and 2.39.)

Whereas, most field crops grow poorly on laterite soils, yields of certain crops such as tobacco, sugarcane, turmeric, ginger, and sweet potatoes are usually satisfactory. Many tree crops such as tamarind, mango, cashew, cassava, coconut, banana, and teak and other forest trees, adapt well to laterite soils.[101]

Continuous cultivation in the tropics invariably results in losses of soil organic matter except where forest trees are left as shade or banana is included in the crop rotation. The large number of banana leaves produced and their shade bring an increase in soil organic matter.[102]

Nye and Greenland state:

> . . . The traditional system of shifting cultivation in the forest admirably protects the soil from erosion in spite of steep slopes and heavy rainfall. In savanna, erosion losses during a single period of cropping are usually slight because of the gentle slopes; and even on steeper slopes they are not sufficient to terminate the immediate cropping period. Repeated cycles of cropping and fallowing may however cause total ruin to savanna soils because they uncover subsoils rich in iron oxide, which if not indurated already, *become so on exposure.*[103]
>
> However, such areas are also those which frequently have iron-enriched horizons near the surface, and if these are not already indurated, *they may become so as the surface is stripped by sheet erosion.*[104]

---

[101] Prescott and Pendleton, *op. cit.*, p. 42.

[102] P.H. Nye and D.J. Greenland, *The Soil Under Shifting Cultivation*, Technical Communication No. 51 (Farnham Royal, England: Commonwealth Agricultural Bureaux, 1960), pp. 98-107.

[103] *Ibid.*, p. 91.

[104] *Ibid.*, p. 124. (Italics added.)

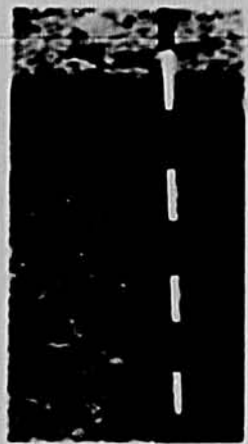

Figure 2.36 Laterite Soils (Ghana): Shallow infertile laterite This shallow laterite is extremely infertile. The topsoil is very shallow and does not support even fair crops without great care in cultivation practices. (Note: pole bands are spaced at 6 inch intervals.) (AFR-530)

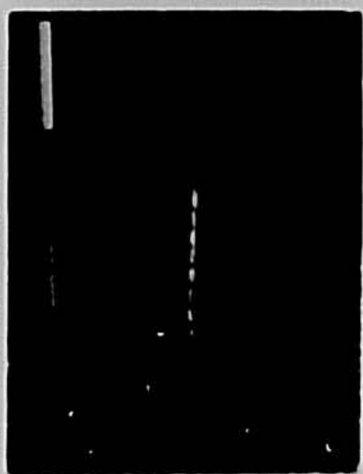

Figure 2.37 Laterite Soils (Ghana): Hardened laterite When laterite is cleared for tractor cultivation the action of moisture and temperature causes hardening into "rocky" soil structure and concrete like "boulders" This effect on the soil shown in Figure 2.36 is illustrated in this figure. This area is part of a large former Government of Ghana mechanized farm using Russian equipment. It was first cropped in 1963 and abandoned in 1966 because of low yields due to the shallow laterite. (Note: the tape is measured in inches and pole bands at 6 inch intervals.) (AFR-531)

Figure 2.38 <u>Laterite Soils (Ghana): Crop failure on shallow laterite</u> Maize crop growing on this shallow laterite has proved almost a complete failure. (AFR-532)

Figure 2.39 <u>Laterite Soils (Gambia): Hardened laterite boulder</u> A laterite boulder in the middle of a bush fallow (shifting cultivation) field where the bush fallow has not been sufficiently long to prevent the laterite from hardening. The boulder is on a farm near Sapu, Gambia, where the cropping system is: groundnuts -- pearl millet -- fallow (each for one year only). (Note: the tape is measured in inches.) (AFR-533)

Three conditions are necessary for hardening of laterite:

1. An adequate supply of soluble iron, either by an inflow of iron from surrounding areas or by an outflow of other constituents and a residue concentration of existing iron.
2. An alternating wet season and dry seasons of approximately equal duration, with sufficient rain in the wet season to continuously saturate the zone of iron segregation.
3. A level land surface with a slowly permeable layer where the iron-concentrated horizon can develop during the wet cycle in a periodic water table or at least in a zone of saturation.[105]

In summary, enrichment in iron is required to produce a material that will harden. If the material is coarse textured, not much enrighment is required; the finer textured the material, the greater the accumulation of iron required. Accumulation may result from the removal of other constituents, it may come from outside sources in seeping ground water or through vertical eluviation, or it may be caused by local rearrangment within the material itself.[106]

The field observations indicate that exposure of soft laterite material to wetting and drying leads to crust formation. The principal factors that accelerate the hardening process are erosion and the removal of forest cover. The two, of course, are often closely related. The mission could not determine how dense a cover or what depth of soil are required to prevent hardening in any given area; this would require specific field experiments over a period of time. *The prevention of hardening is important in connection with some of the plans for mechanization of agriculture that have been contemplated in Ghana and Nigeria.*

From data obtained at Conakry, in Guinea, it appears that the hard crust and the soft material below it have the same chemical composition. They differ only in crystal size and in content of uncombined water. At Nzerekore, Guinea, data were obtained on the time required to form a hard crust. Wetting and drying for a period of 15 years caused a hard, slaglike crust, 1 to 2 centimeters thick, to be formed. The same material used in the walls of a house, continuously dry for the same period, was still soft enough to be scratched with a thumbnail. Thus it would seem that the hardening process is one of solution and crystal growth.[107]

In parts of West Africa, removal of the thin forest for the cultivation of cotton or peanuts increases the drying of the doughy laterite enough to harden it under the very feet of the farmer.[108]

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[105] Alexander and Cady, *op. cit.*, p. 4.

[106] *Ibid.*, p. 10.

[107] *Ibid.*

[108] Charles E. Kellogg, Assistant Administrator for Soil Survey, Soil Conservation Service, U. S. Department of Agriculture, in Alexander and Cady, *op. cit.*, p. 111.

Softening of Hardened Laterite

> So far as we could see, vegetation is the only agent that can prevent or reverse this hardening process. Trees and other perennial woody plants are most effective. Some forestry experiments in Guinea, Dahomey, and Nigeria indicate that some crusts in well-drained positions can be broken up by the roots and litter of trees, perhaps aided by a change in microclimate. This leads to solubilization and movement of iron, probably in a complex with organic matter.[109]
>
> The establishment of vegetation is an important factor in breaking up laterite crusts and in reversing the hazard of hardening. Rosevear (1942)[110] reported a measurable reversal of hardening under a teak plantation in 16 years. Softening is caused by reduction and chelation by organic matter, by the physical action of roots, and by the prevention of extremes, of drying and high temperature.[111]
>
> Little specific information on the reversal of hardening is available. The information obtained on the causes of hardening, however, indicates the direction in which research can be oriented.[112]
>
> The data, observations, and interpretations show that it may be entirely feasible to prevent the hardening of laterite that is still soft if some control of land use is possible.[113]

The Need for Soil Structure Studies in Ghana

Ahn has subjected highly weathered sandy loam and clay loam soils of central Ghana to mechanical analyses, with and without a dispersing agent, and concluded:

> The binding of the clay fraction by iron oxides to silt- and fine and medium sand-sized aggregates, and the marked stability of these aggregates, appear to be important factors affecting the use of highly weathered tropical soils and to contribute to their favourable physical properties, including their porosity and good drainage . . . It is very desirable that soil scientists pay careful attention to this problem and try to follow, by careful observation, any physical changes in the various soil types cultivated, and attempt to associate them with the fundamental characteristics of the soil so that a greater knowledge of changes to be expected on cultivation can be built up.[114]

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[109] Alexander and Cady, *op. cit.*, p. 5.

[110] R.D. Rosevear. "Soil Changes in Enugu Plantation", *Farm and Forest*, Vol. I, No. 5, 1942.

[111] Alexander and Cady, *op. cit.*, p. 12.

[112] *Ibid.*

[113] *Ibid.*

[114] Peter M. Ahn, "The Effects of Large-Scale Mechanized Agriculture on the Physical Properties of West African Soils", *Ghana Journal of Agricultural Science*, Vol. 1, 1968, pp. 35-40.

Research on soil structure must be an integral part of all mechanization research in Africa. Highly weathered tropical soils have good surface soil structure *when first cleared.* What happens to desirable surface soil structure when the soil is cultivated continuously, however, is the crucial problem. Soil capping (surface crust formation), surface soil erosion, and hardening of the ground-water laterite layer are reported by researchers and observers in Africa. *Massive research efforts in Africa must be concentrated on these physical problems before continuous soil productivity under mechanized cultivation can be advocated.*

The following case emphasizes the importance which a profit-oriented private farmer attaches to proper soil knowledge. In Ghana a government farm established in 1962 at Prang, 118 miles northeast of Kumasi, was abandoned in 1966 because of low crop yields resulting from the hardening of the laterite soil layer when exposed to the conditions of additional wetting and drying. Tractorized farming had been employed in contrast to the traditional hand system of shifting cultivation. After being abandoned, the farm was sold to an individual who paid for a soil survey that recommended the establishment of permanent pasture on the thin laterite soils and field crops on the deeper, potentially productive soils (Figure 2.40).

The scientist in charge of the Ghana Soil Survey[115] has prepared a map of Ghana to delineate areas where soils can be safely tractorized, areas unsafe for tractors but suitable for animal-powered agriculture, and areas where the traditional hoe-culture should be continued (Figure 2.41).

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[115] Mr. Henry Obeng

Figure 2.40 <u>Laterite Soils (Ghana): Deep fertile lateritic soil</u> Deep lateritic soil is physically a good medium for plant growth; but it needs fertilizers and other modern inputs to assure good crop yields. This figure illustrates the good quality of the laterite soil on the Prong Farm, central Ghana. (Note: Pole bands are spaced at 6 inch intervals.) (AFR-534)

Figure 2.41 Soil Capability for Mechanized Cultivation (Ghana)
Source: Henry B. Obeng, "Land Capability Classification of the Soils of Ghana under Practices of Mechanized and Hand Cultivation for Crops and Livestock Production," *Transactions: Ninth International Congress of Soil Science* (Adelaide: 6-16 August), Vol. IV, Paper 23, pp. 215-223. (See Legend next page.)

Legend to Figure 2.41

A. Land where more than 50 percent of the soils are capable of being cultivated continuously with tractors, oxen, or by hand with little or no soil hazard. Restrictive layer of laterite (ironpan), or bedrock or gravelly layer, or slowly permeable soil material may lie below 64 cm. Includes U.S. Soil conservation Service Land Capability Classes I to IV. Comprises 20 percent of the total area of Ghana.

B. Land where more than 50 percent of the soils are capable of being cultivated intermittently by oxen or by hand with a system of bush fallow. Not capable of being farmed by tractors because of soil hazard. Restrictive layer of laterite (ironpan), bedrock, stony or gravelly layer, or slowly permeable soil material may lie between 32 and 64 cm. Includes U.S. Soil Conservation Service Land Capability Classes V and VI. Comprises 33 percent of the total area of Ghana.

C. Land where more than 50 percent of the soils are not capable of being cultivated except in isolated patches because the soil is too shallow (less than 32 cm) to lateritic (ironpan) or bedrock, too stony or too gravelly or too slowly permeable; or too rolling topography. Includes U.S. Soil Conservation Service Land Capability Classes VII and VIII. Comprises 47 percent of the total area of Ghana.

D. Saline alluvial soils capable of being cultivated continuously with tractors, oxen, or by hand for the production of specialized crops if adequate and continuous artificial drainage is provided. Comprises less than one percent of the total area of Ghana.

CHAPTER III

ENGINEERING AND TECHNICAL ANALYSIS OF AGRICULTURAL PRODUCTION OPERATIONS

Introduction

Whatever the level or scale of agriculture, the farmer is a tool user and in Africa he is primarily a hand tool operator. *In the traditional subsistence farming community, past improvement has come mainly from the farmers' increased skills in using old tools rather than development or invention of new or better ones.* However, *technological improvement has in fact come more from the invention or introduction of better tools and power systems than from greater dexterity in the use of old ones.*[1]

In most of Equatorial Africa today, the land is still tilled mainly by hand methods with locally-made tools. Tools have evolved slowly over generations of use, and many bear striking resemblance to ancient tools. Moreover, *a need for hand tools will continue in African agriculture for many decades to come.* "Even today on motorized holdings, man still spends two-thirds to three-fourths of his working time with hand implements."[2]

Labor in the Tropical zone of Africa is generally underemployed and, except for seasonal peak demands, many basic farm operations can still be done economically by improved hand-powered implements. Use of improved tools has a direct effect on agricultural production. *Unless land is adequately prepared and cultivated in conjunction with better cultivation practices, the use of improved seeds, fertilizers, irrigation, and plant protection measures will not have the desired effect on production yields.* Returns from labor and money invested may not be large enough to encourage the adoption of improved-farming practices if inefficient hand tools are used.[3] *Ineffective hand tools waste energy, increase man-hours, and are often responsible for low levels of production and negative attitudes detrimental to the development of a viable agriculture.*

Most older hand tools for cultivating tropical soils were made of wood (in southwest Ethiopia as recent as 1930), and minimum tillage was

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[1] R.H. Cochrane, *Cut Flowers - No Roots: An Outline of Problems Affecting Agriculture in Developing Countries* (mimeographed) (Victoria, Australia: Community Aid Abroad, n.d.), p. 29.

[2] H.J. Hopfen, *Farm Implements in Arid and Tropical Regions*, (Rome: Food and Agricultural Organization of the United Nations, 1960), p. 4.

[3] Central Treaty Organization, *Farm Tools and Implements*, Traveling Seminar in Iran, Pakistan, Turkey, (Ankara: CENTO, September, 1968), p. 15.

practiced long before it became popular with modern power farmers. In the past half century, wearing parts of tools have been faced with or made of metal to prolong their life and reduced the human energy required. Each area or region tends to develop its own and often unique implements, but the basic designs and methods of use are strikingly similar throughout Equatorial Africa. Many of the traditional tools and some of the improved tools and techniques which offer major opportunities for improvement and change in subsistence agriculture are discussed in this section.

No single tool or method can suit all conditions. In southern Ethiopia, Sudan, northern Kenya and Tanzania, the cultivator for the most part farms on the flat; while in Nigeria, Ghana, Senegal and Ivory Coast, he usually makes mounds or plants on ridges. The tools used are shaped and sized to perform these operations most expeditiously: the Nigerian *garma* and Ghanaian *kpakpla* are built to move soil and pile it in heaps and ridges, while the Ethiopian *doma* and Kenyan *jembe* are made to dig and stir the top soil and chop out weeds. *With introduction of specialized crops, development of export markets and utilization of animal and engine power, the differences in tools become more significant.* Ultimately, as farm practices become commercialized, market conditions dictate not only the type of tool and its power source but also its application and economic value.

Tillage

The main object of tillage is to assist the natural processes which create favorable soil conditions for the germination of seeds and growth of plants. In hotter climates the natural processes are more intensive and there is less need for heavy primary tillage. Hopfen states:

> . . . in arid and semi-arid areas with a high average soil temperature and . . . with frequent dry winds, the need is to break the soil without inverting it in order to collect and store as much moisture as possible and to delay the natural decay of vegetation. This is best done with breaking non-inversion or semi-turning types of plows . . . . Tropical rain-fed areas with a high average soil temperature and with a dense vegetative cover do not need much tillage, as the shade providing plants preserve natural tilth and moisture.[4]

Technical Factors and Constraints

Hand Operations

1) Tools and Practices

The hand-operated tools used for tillage in Equatorial Africa are mainly hoes, spades and shovels. All are universal tools with different sizes

[4]Hopfen, *op. cit.*, pp. 35-36.

and shapes according to specific purpose, prevailing soil conditions, locally available materials and local customs. (Figure 3.1.) Definite preferences for specific tools for primary tillage exist within different regions. The spade is used in the Middle East, the digging hoe in Tropical Africa and the Far East, and digging hooks and picks in West Africa. Special tools have evolved in certain areas, like the long-handled double-prong spade in Ethiopia, the short-handled ridging shovel in Nigeria and the long-handle hand plow in Senegal. Similar hand tools are used for seedbed preparation as are used for primary tillage except that the blades may be wider and forked hoes also may be used. For light work, forked hoes should have at least four tines.

2) Power Required

In most countries, heavy tillage operations are carried out by men working singly with individual tools. In some countries, spading is done in teams as in Ethiopia. In some parts of Asia and northern Africa, two men operate a special shovel to prepare ridges and furrows and levees for irrigated crops; one man pushes and controls the long-handled shovel while a second man guides the blade with a rope.

> A man normally works at a rate of 7 to 10 kg./sec., varying from 5 kg. at 1.1 m./sec. with a crankshaft, to 64 kg. at 0.15 m./sec., when treading with his own weight on a water ladder. During continuous work, he produces about . . . 0.1 h.p. For short periods he can develop 0.4 h.p. The average force a man can exert is equal to about one-tenth of his own weight.[5]

Also, as emphasized by Hopfen:

> Working with the spade is very strenuous. The digging depth with long-handled spades and a foot rest is between 25 and 35 cm. . . . . The working depth of short-handled spades is generally 22cm. At that depth a man can dig about 20 m.^{2} of medium arable soil per hour lifting approximately 44 cubic meters or roughly 80 q. of earth [or about nine tons].[6]

The digging hoe is a universal implement serving for ridging, surface cultivation and weeding. The steel blade usually has a socket or a hole for a sturdy wooden handle, with an angle from 45 to 90^{o} between the working part and handle. Blades of digging hoes vary considerably according to the users' strength, local customs and soil conditions. Sizes are small for women and children and larger for men; shapes and weights are long, narrow

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[5] *Ibid.*, p. 4.

[6] *Ibid.*, p. 40.

Figure 3.1 Northern Ghana: Hoe used in upland farming More than 90 percent of farming in Equatorial Africa is done with the short-handled hoe, similar to this one being used near Tamale. A more efficient source of farm power is an essential factor in increasing agricultural productivity. While there are many variations in method of attachment and style, shape and size of blade and handle, there is .. remarkable similarity in indigenous small hand tools across Equatorial Africa. (AFR-523)

and heavy for compact soils and short, wide and light for light soils. Short handles are common but long handles are not unusual.

Capacities of digging hoes depend on soil hardness, moisture content, vegetation, climate, temperature, health, size and condition of the individual and the type and depth of tillage. *Digging to 25 cm. depth may take as much as 500 man-hours per hectare.*

3) Time Required

For heavy spading in compacted soils to depth of 20 to 25 cm. at 20 $m.^2$ per hour, it would take one man five hours to dig up 100 $m.^2$. A normal work day in many parts of Equatorial Africa is about five hours long. *At this rate of work, it would take one man 100 days or 500 hours to spade one hectare.*[7] *This illustrates the severe limitation of hand labor and explains why most land is hand-worked by community teams.* A five-man team can prepare one hectare in 20 days.

Primary tillage with digging hoes proceeds at a faster pace because depth is limited to 10 to 15 cm. and the soil is not turned but simply rolled back with quick short strokes. If it took 300 hours to till one hectare by hand, it would take 50 man-days based on a six hour day. (Figure 3.2.)

Seedbed preparation may include digging or making holes for plants or seeds. In soft sedimentary soils of southwest Ethiopia, a *slow* farmer spends eight days to dig sorghum holes on an average field of 0.7 hectares, while a *fast* farmer takes only three days. The *average* farmer spends about five and one-half days or approximately eight days per hectare.

4) Skill and Management Required

Farmers become skilled in handling simple soil working tools. Perseverance, good health, and a large labor supply are needed to farm entirely by hand. *In areas with distinct wet and dry periods, tillage time is very limited; the amount of land a family can farm depends on how much they can till by the optimum planting dates. Timeliness in completing the basic land preparation before planting usually is very critical.*

In Nigeria, the most critical problem for owners is land preparation, while for non-owners, with only annual crops, the bottleneck is weeding.[8]

5) Costs Involved

Wage rates vary considerably in Equatorial Africa between and within countries. Rates are high near larger cities and for heavy, hard work; and

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[7] *Ibid.*

[8] Warren Stetler, Agricultural Engineer, University of Ife, Ile-Ife, Western Nigeria, Personal Communication, 8 November 1968.

Figure 3.2 Southern Ghana: Hoe used for tillage and weeding Contrasted to Figure 3.1 this blade uses a perpendicular eye socket permitting a straight handle to be inserted from the back to facilitate tightening, while the other uses an eye socket parallel to the blade requiring a right-angled or curved handle. (AFR-506)

Figure 3.3 Ethiopia, Koka Dam (east central highlands): *Maresha* plow and yoke Plows are made of local materials except for the metal point and O-ring strap used to brace the point. This *ard* type soil-breaking tool has distinct advantages in arid and semi-arid regions for moisture and soil conservation. In humid tropical regions with heavy soils it is also favored because of its lighter draft and fewer scouring problems. (AFR-236)

generally low in remote rural areas and for light, easy tasks. Actual wages paid for hand labor are given in Table III. 1, for a standard government workday of eight hours.[9]

Animal Operations

1) Tools and Practices

There are two basic types of plows for primary tillage, the symmetric breaking-type and the asymmetric moldboard turning-type.

a) Breaking-plows The breaking-plow or *ard* is the common tillage implement used in areas where soil temperature is high during the main growing season. Beam, body and handle are commonly made of wood, and the share of iron. It produces a slightly ridged tilth, does not invert the soil, and leaves dead vegetation on the surface of the tilled ground. It has either a breaking-and-digging or a breaking-and-cutting action.

Two basically different types of *ards* can be traced back to the dawn of animal-powered agricultural history.[10] The beam *ard* usually has a curved beam originally pierced by a spear-like body-handle unit. This plow later developed into a separate body with the handle attached to the beam. (The present-day Ethiopian plow is a good example of the ancient beam *ard*. Figure 3.3.) The body *ard* has an upward-inclined body tapering into a handle, and is pierced by the beam which makes it sturdier and heavier for deep tillage. The Egyptian, Afghanistan, Turkish and Indian plows are typical body *ards*.

The working part of the *ard* originally was carved from hard wood, later developing into an iron or steel share. This share exists in two basic forms: a socket share, (like the Ethiopian plow) which is slipped over the nose of the plow-body, and a tang share which fits into a groove where it is held by a clamp on the wooden body. The tang share is normally used in dry, stony soils; the socket share is generally used for other soils found in the wetter rain-fed areas of Equatorial Africa with heavier, sticky clay and loam bases.

The present beam *ard* and other *ards* generally have one handle. Prehistoric art shows the first beam *ards* used by the Sumerians and the early Egyptians had two handles and sometimes also a seed-tube. The present Arabian-type plow used in Eritrea in northern Ethiopia is equipped with one

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[9] These are actual wage payments for hired labor as recorded by the cited sources. No attempt has been made to put these wage rates on a comparable basis in terms of work capacities of a labor unit, or in terms of labor productivity.

[10] *Ibid.*, pp. 44-47.

TABLE III. 1 COMPARATIVE COSTS OF UNSKILLED AND SKILLED LABOR IN SELECTED AFRICAN COUNTRIES

Country	Year	Hand labor cost per day	Semi-skilled machine operator cost per day	Tractor operator cost per day
		dollars	dollars	dollars
Northeast Nigeria[a]	1964	0.56	0.72	0.96
Southern Nigeria[b]	1968	0.80	0.93-1.87[k]	1.12
Southern Nigeria[c]	1968	1.20	3.36[l]	2.80[m]
Ghana[d]	1968	0.70	1.00	1.12
Ghana[e]	1968	1.00	1.12	1.28
Ivory Coast[f]	1968	1.36	2.86[l]	2.04[m]
Kenya[g]	1968	0.88	1.25-1.75	1.20-1.50
Ethiopia Lowlands[h]	1968	0.50	2.00	1.33
Ethiopia Highlands[i]	1968	0.32	1.50	0.80
Ethiopia Commercial Operations[j]	1968	0.60	2.94-3.33[k]	2.00-2.13

[a]T.J. Shambaugh, Machinery Advisor, USAID, Maiduguri, Nigeria.

[b]J. Hewitt, Manager British East and West Africa Company (MF), Apapa, Nigeria.

[c]A. Hollingshead, United Africa Company (Caterpillar), Lagos, Nigeria.

[d]A.K. Sokeh, Mechanical Superintendent, Ministry of Agriculture, Amasaman, Ghana.

[e]J.B. Kore, Crops Research Institute, Kumasi, Ghana.

[f]Z. Leventhal, Director of Works, Motoragri, Abidjan, Ivory Coast.

[g]C.M. Downing, Mechanization Specialist, Ministry of Agriculture, Nairobi, Kenya.

[h]S.Z. Moczarski, Rural Institutions Extension Specialist, FAO, Awash Valley Authority, Addis Ababa, Ethiopia.

[i]Solomon Bellete, Agricultural Economist, Institute Agricultural Research, Holetta, Ethiopia.

[j]M. Harley, Machinery Manager, Tendaho Plantations Share Company, Dubte, Ethiopia.

[k]Wheel-tractor mechanics.

[l]Crawler-tractor mechanics.

[m]Crawler-tractor operators.

handle and a seed-tube, as are the plows used in the middle Awash Valley where maize has been grown for centuries.[11]

b) Moldboard Plows The Western moldboard plow is perhaps a more efficient destroyer of weeds than any other cultivation implement but it has a heavier draft than digging- and breaking-*ards*. The moldboard action is different from breaking *ards* as the share cuts loose a rectangular block of soil and the moldboard turns the slice into the previous furrow. To offset the side-thrust, the landside takes the horizontal pressure on the furrow-wall and the sole the downward pressure of the implement on the furrow bottom. The weight and sliding action of the plow in heavy soils tends to create an impermeable layer or plowpan on the furrow bottom. This is undesirable in all but purposely-puddled irrigated lowland fields.

The moldboard plow is commonly found in Southeast Asia where it is used in rice and general crop production.[12] Some use is made of them in eastern Africa, extensive use in South Africa but only limited application in western Africa. (Figure 3.4.)

c) Ridging Plows Ridging plows are used extensively in both western and eastern Africa, south of the Sahara, for groundnut and cotton production.

In Nigeria and Ghana, the Ransome Emcot Model S-30 is currently most widely distributed. It superceded the first Ransome DY ridging plow used from about 1933 to 1962. These plows are both heavy and robust, and small oxen common throughout Equatorial Africa have trouble pulling them. Farmers in western Africa, unlike those in Kenya and Tanzania, have never made use of multiple pairs (4, 6 or 8) of oxen hitched in tandem to a plow. There has been a demand for a light-weight ridger that could be handled by a pair of small oxen; one developed by the Christian Service Committee in northeast Ghana has been well-received by farmers.

The Ransome Emcot S-30 ridger has a curved forged-beam, a large adjustable lister-body, double handles, a depth-control wheel in front and chain pull. (Figure 3.5.) It also features a rear control-rudder extending below the heel some 20 cm. It differs from the old Ransome DY ridger in the shape of the beam and handles and larger adjustable moldboards and wings. The S-30 ridger weighing 49 kg. is especially designed to build 90 cm. ridges and gradually hill-up root-crops to a depth of 30 cm. In sandy soils the wear is severe, requiring a new share and shin about every 6 hectares and a new

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[11] S.Z. Moczarski, Rural Institutions Extension Specialist, FAO, Awash Valley Authority, Addis Ababa, Ethiopia, Personal Communication, February 1969.

[12] Hopfen, *op. cit.*, p. 54.

Figure 3.4 Canadian plow owned by an animal-powered farmer in Tanzania This man had been using tractors, but has now returned to ox power. (AFR-129)

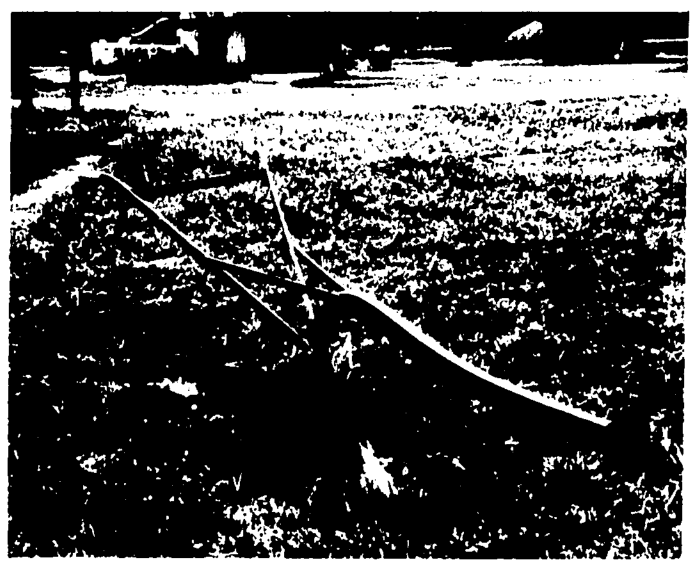

Figure 3.5 Emcot ridger widely used in northern Nigeria and Ghana There are over 60,000 of these units in Nigeria. It is the most common animal-drawn tool owned or used by animal-powered farmers in English-speaking western Africa. (AFR-334)

moldboard every 12 to 18 hectares.[13]

Thousands of Emcot Ridgers were imported from England until 1966 and, as pointed out by Haynes, "it is the only implement owned by most mixed farmers.[14] In 1966, John Holt Bartholemew set up a small implement factory in Zaria, northern Nigeria, called John Holt Agricultural Engineers, Ltd. In the first year 4,000 units were manufactured and currently 8,000 to 10,000 plows are being produced per year, or 20 to 33 percent below maximum capacity. The entire plow including the moldboards and 90% of the parts, is made in Nigeria except for the bolts, shares and two or three castings. Exported to Ghana, Mali, Togo, Dahomey and the Congo, a single plow wholesales for $56.00 from factory, and for $53.20 in lots of 25 or more. Plows are sold to the Nigerian Native Authorities and to small dealers for $58.00 to $61.60.

In Ghana, the John Holt Ford-distributor wholesales them for $57.80 to the Farmers Cooperatives who sell them at the same list price. Parts are stocked by John Holt dealers, stores, and Farmers Cooperatives.[15]

The town of Mubi in northeast Nigeria sold 147 plows in 1968 , disassembled in case lots of ten, for $54.60 each plus transportation cost. Prices differ depending on the location and demand. The official Nigerian Native Authority plow price was $67.20, but the going market price ranged from $70.20 to $78.40.[16]

A factory in Kano, Northern Nigeria, makes CFAO Ridging Plows. Although little information is available, it is reported that 20,000 plows have been sold. The price has been $46.20, but the Nigerian Native Authority is now subsidizing the plow so that the cost to farmers is only $28.00.[17]

A lightweight ox-plow was designed for northern Ghana by Egbert Dÿkstra, a Dutch engineer in 1966 at the request of Karel Rigter, agricultural missionary with the Christian Service Committee at Garu. After preliminary testing, 40 models were sold to interested farmers. The plow has gone through several modifications.[18] The original model had an

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[13]John Whitney, Formerly Research Assistant, Consortium for the Study of Nigerian Rural Development, Kano, Northern Nigeria, Personal Communication, November, 1968.

[14]D.W.M. Haynes, *Ox-drawn Implements*, Papers on Agricultural Engineering in Northern Nigeria (Kaduna, Nigeria: Ahmadu Bello University, Institute for Agricultural Research and Ministry of Agriculture, 1964), p. 1.

[15]J. Turner, Factory Manager, John Holt Agricultural Engineers, Ltd., Zaria, Northern Nigeria, Personal Communication, November, 1968.

[16]Whitney, *op. cit.*.

[17]*Ibid.*

[18]Karel Rigter, Christian Service Committee, Garu, Ghana, Personal Communication, November, 1968.

adjustable hitch for overcoming side draft, but since the farmers always used the center hole it was simplified to a single center hook. (Figure 3.6.) The original skid standard wore rapidly in the sandy soils and was replaced by an adjustable standard with a sealed grease-packed roller-bearing wheel as the original adjustable-wing moldboards were always used in one position to make a standard-width furrow 50 cm. wide, the final prototype was designed with fixed wings and with each moldboard made of one piece rather than two. The share was strengthened and attached with flush bolts; the handles made adjustable for height; and the gauge wheel and ridging element secured with strong hand-twist bolts to permit quick adjustment and easy tightening.

These improved ridging plows represent the second group of agricultural implements introduced by CSC into northeast Ghana. The first order of 40 production models was quickly sold to interested farmers early in 1967. The present unit is made of simple, straight, bent or bolted pieces which can be made and assembled by a local artisan or blacksmith. It can be shipped and stocked disassembled. (Figure 3.7.) If the plow could be made locally with semi-skilled labor from standard materials, a further reduction of 25 percent of its imported price might be possible. Sales to August 9, 1968 are shown in Table III. 2, along with prices of components. Farmers paid cash for the plows; no credit was given.

The CSC is now developing attachments for insertion into the basic frame in place of the ridging element, such as a groundnut lifter, fertilizer placer, weeder, cultivator, and moldboard plow. The greatest maintenance problem has proven to be lubrication of the wheel bearings.

The CSC did not promote the second order of ridging plows because they wanted farmers with more powerful oxen to buy the heavier and more expensive Emcot Ridger available through the Bawku Co-op Farmers' Union for about $59.00.[19]

The MPLOS Ridging Plow, manufactured by John Darbyshire and Company, Ltd., Somercotes, Derbyshire, England, is finely finished and appears designed for good service and long life. Farmers find it easy to control; and it can be pulled by one or two animals. Two types of ridging bodies are available: a larger model with a 35 cm. share and moldboards which expand from 30 to 75 cm. wide; and a smaller unit with a 30 cm. share, moldboards and shins 5 cm. lower, adjustable from 25 to 60 cm. in width. Wings can be added if desired and both bodies make a ridge with a wide base and round top. The ridger has a channel-steel hook-shaped frame, adjustable head wheel and hitch point, and replaceable heel and shin pieces.

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[19] *Ibid.*

Figure 3.6 Garu, Upper Region, Ghana: The production model of a simple, light-weight, low-draft, all-steel ridging plow The complete plow shows its relative size to an average size Ghanaian. The gauge wheel, plow standard and handles are adjustable for different sizes of men and oxen. To November 1968.51 plows have been sold to small farmers by the Christian Service Committee (CSC). The plow components are made in Holland and shipped disassembled to Ghana. The CSC plans to furnish attachments for groundnut lifting, cultivating, and fertilizer sidedressing. (AFR-239)

Figure 3.7 Garu, Upper Region, Ghana: Dutch-built CSC ridging plow This disassembled view shows the bottom of the frog and the moldboard assembly. The completed plow is sold slightly below cost ($38.00) to farmers. (AFR-242)

TABLE III. 2 SALES AND PRICES OF CHRISTIAN SERVICE COMMITTEE RIDGING PLOWS AND PARTS: GHANA[a]

Item	Original quantity	Sales to date	Price
Complete plow	104	11	$37.45
Wheel and fork assembly	n.a.	1	6.90
Wheel, bearing and grease caps assembly	6	0	2.96
-Axle plus split pins	24	2	.49
-Bearings	20	2	.74
-Grease seals (two)	20 pr.	2	.20
-Split pins	21 sets	2	.05
Element complete assembly	+ 40	7	13.80
-Point (small)	± 100	17	1.97
-Bolts and nuts	100	21	.06
Chain	n.a.	n.a.	n.a.
Spanner	+ 72	18 (-4)	.39

[a]Sales from June 1 to August 9, 1968. The first group of 40 complete plows designed by Egbert Dÿkstra was sold in 1967/68.

This chain-pulled ridger is recommended for use when the ground has not been destumped as it is easily maneuvered around obstacles.

d) New Types of Moldboard Plows During Study Team travels, a limited number of improved animal-drawn turning plows were seen being tested, distributed and used in eastern Africa. In central, northern and southern Tanzania, in central, eastern and northern Kenya and in central Ethiopia there is considerable interest in moldboard plows. The Tanzania Agricultural Machinery Testing Unit (TAMTU), near Arusha, has tested a number of plows and other implements and given them to farmers to use under typical farm conditions [20] TAMTU is also working on a modified design of a wheel-carried, single-furrow, self-guiding moldboard plow that can be manufactured locally. A number of prototypes have been built and the latest model looks promising. Currently available to farmers are several German and Indian plows that have been introduced to take the place of the now-banned but very successful SAFIM plow, still made in South Africa.[21] The Kenya Agricultural Machinery Unit (KAMU) and the Chilalo Agricultural Development Unit (CADU) in Ethiopia are likewise testing and promoting the use of improved moldboard plows.

The Gallon plow made by Efka Klausing, West Germany, is a light-weight, chain-pull, two-wheel plow that requires two oxen under good moisture

[20]Ministry of Agriculture, Forestry and Wildlife of Tanzania, *Test Reports* Nos. 4/62/63; 5/62/63; 6/62/63; 2/65/66; 3/66/67; 4/66/67, (Tergeru, Arusha, Tanzania: Northern Research Center, Tanzania Agricultural Machinery Testing Unit [TAMTU]).

[21]South African Farm Implement Manufacturers, Ltd., Vereeniging, South Africa, associated with Massey Ferguson Ltd., Toronto.

conditions in light to medium clay soils, and four oxen on heavier soils or under dry, hard conditions. It cuts a furrow 25 cm. wide, 12 to 15 cm. deep and does a good job of covering trash and fairly heavy vegetation. One of its principal features is self-guidance, with the furrow wheel acting as a steering guide. It was observed in use with four medium-sized oxen in tandem pairs moving at a brisk walk. Two operators controlled the plow and the teams with whip and voice. The interviewed farmer was very pleased with the plow's performance and ease of use. (Figure 3.8.) He had previously used a tractor for four years but has gone back to animal power because he could not afford to pay the high operating charges and loan cost of the tractor.

The same basic design is available in a two-furrow model with steel frame, land and furrow wheels.[22] Its twin moldboards cut a path 58 cm. wide and require at least four large oxen to pull it and under difficult conditions would undoubtedly need six or more. It is also reported by the farmer as easy to use as a self-guiding plow.

The single-furrow Cockade I plow, manufactured by P. Mohlhoff, West Germany, carries a low price of $16 in Tanzania. It cuts a furrow 12 to 20 cm. wide and plows to a depth of 6 to 18 cm. For an all-steel plow, it is light, weighing only 34 kg. The main beam of 10 kg. channel-section steel is equipped with an 18 cm. steel gauge wheel, a 1.5 kg. solid forged steel share, and 3.2 kg. steel moldboard. A knife coulter is also available.

Either a fixed or adjustable ridger body can be attached to the beam in place of the plow body. The Cockade 85 body makes 90 cm. ridges, and the Model 86 adjusts for 30 to 90 cm. ridges. The former, costing only $10, makes an inexpensive dual-purpose implement for the cash-short farmer. The Cockade ox-plows are currently being imported into Tanzania in large quantities.[23]

The Cossul steel plow made by Cossul & Company Pvt. Ltd., Kanpur, India, appears identical in design to the Cockade I above, with slightly different specifications. The furrow has a width of 23 cm., a maximum depth of 15 cm., weighs 38 kg. and sells for $14. Share, breast, and landside are forged steel bolted to a pressed-steel bottom. Depth can be adjusted by raising or lowering the head wheel, by shifting the vertical hitch or plow clevis, or by adjusting the length of chain hitched to the plow. The ridger attachment, patterned after the Emcot with wing

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[22] Ministry of Agriculture and Cooperatives, *Availability of Ox-drawn Equipment*, Ref. No. P/Q (mimeographed) (Dar es Salaam, Tanzania: September, 1968), p. 3.

[23] *Ibid.*, p. 3.

Figure 3.8 Arusha, Tanzania: Improved moldboard plow and four oxen
The Tanzanian Agricultural Machinery Testing Unit has loaned this improved self-guiding German plow to a co-operative farmer. Note guide wheels and chain in place of tongue. (AFR-128)

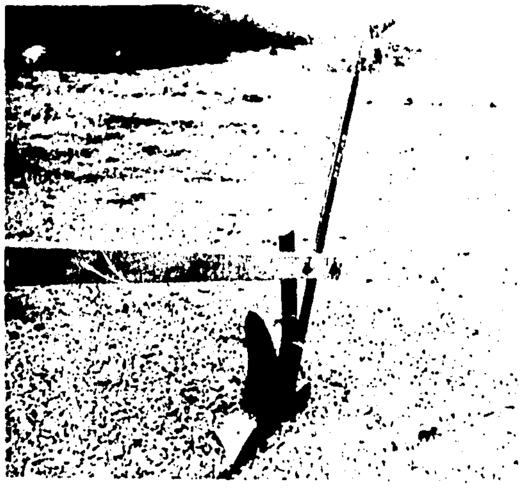

Figure 3.9 Improved Far East (Indian type) steel moldboard plow This plow is extremely simple n design and can be locall:' produced by trained blacksmith.. While very light-weight it is sturdy and maneuverable. The single handle fits the traditional method of whip and voice control and leaves one hand free for directional guidance of both oxen and implement. (AFR-465)

attachments for making 90 cm. ridges, is more expensive at $22.00.

The Cossul ox-plows are currently imported into Tanzania in large quantities and available throughout the country. Credit for the purchase of ox-drawn equipment by co-operative unions and individual farmers is available through the National Development Credit Authority (NDCA).[24]

The improved Far East moldboard plow, an improved simplified all-steel moldboard plow with wooden beam developed in India and Pakistan, is being tested in Ethiopia by CADU. Designed for small oxen it has only one handle allowing the other hand to be used for animal control. In preliminary tests it performed very satisfactorily. It can either be imported or fabricated locally at very reasonable cost. (Figure 3.9.)

VITA improved village plow was developed in Afghanistan by field staff members of Volunteers International Technical Assistance (VITA). A large number of native plows were studied and the best features of each combined into this improved simplified version called the village plow. It was brought into eastern Africa by VITA volunteers and currently is being evaluated in Ethiopia by CADU. It performed well in preliminary tests. (Figure 3.10.)

e) New Types of Multi-Purpose Tools and Toolbars In both eastern and western Africa, a number of improved multi-purpose tools have been tested, demonstrated, and recommended to farmers. The greatest disadvantage is the relatively high price characterized by present low volume production. *Farmers everywhere like them, and would purchase these tools if credit were available and if they were able to increase production efficiency enough to warrant the extra cost.* Both the French and the English have pioneered work on animal-drawn toolbars, with the National Institute of Agricultural Engineering (NIAE) in Silsoe, England taking the lead in early development in the United Kingdom, and the Mouzon Frères Société, Seine-et-Oise, Paris, pioneering work in France. In general, the approach has been to meet the farmers' needs at lowest cost with a skid-mounted animal-operated tool which can be used for all basic field work with primary emphasis on tillage and cultivation. A more versatile and sophisticated toolbar is mounted on rubber tires which makes it usable for transport and cart work on any surface.

NIAE animal-drawn toolbar was tested in Nigeria and East Africa by agricultural research institutes and by agricultural machinery testing units. Patent rights have been granted to two firms to produce it. One firm in England is now manufacturing it in quantity and placing emphasis

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[24] *Ibid.*, p. 1.

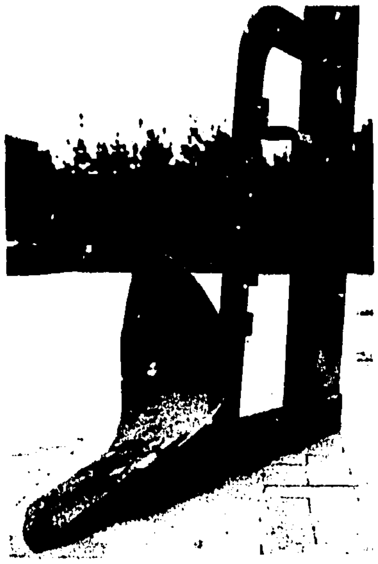

Figure 3.10 Improved Middle East village plow This moldboard plow was designed by field staff members of Volunteers International Technical Assistance (VITA) from the best features of a number of Afghanistan native plows. This sample was brought into Ethiopia for trial by the Chilalo Agricultural Development Unit (CADU). (AFR-435)

Figure 3.11 NIAE (British-designed) all-purpose animal-drawn toolbar The National Institute of Agricultural Engineering has pioneered work on multi-purpose animal draft implements and tools for developing countries. The unit comes in both low and high arch designs and features a removable box or platform for hauling as well as attachments for multiple parallel-row planting, cultivating and spraying. (Photo courtesy of T.J. Willcocks, NIAE, Silsoe, England)

on overseas promotion having already supplied 2,000 units. Gambia has approved it for use in their program of improved farming with ox-drawn equipment. A high-arch version also has been developed for use in eastern and central Africa.[25] (Figure 3.11.)

In Kenya, Cooper used the NIAE prototype toolbar fitted with a victory-type plow to break and turn difficult pasture land. "In addition to plowing, this toolbar can be fitted with attachments for seedbed preparation, tie-ridging, inter-row cultivations and transport purposes. In all operations, the ox driver may be seated on the implement."[26]

APLOS animal-drawn toolbar, based on the NIAE design, is manufactured by John Darbyshire and Co. Ltd., England. The implements are well finished and come in several models. Table III. 3 lists attachments and factory prices for the three current models, Mark II, Mark III and Mark IV. The toolbar is designed to be pulled by two oxen, and to permit the operator to walk or ride as work permits. The basic unit consists of an all-steel tubular frame with a hand-activated lift-type toolbar on which various attachments can be mounted or fastened. A rigid tongue of wood is attached to the animals' neck yoke to permit positive control of all implements, with well-trained oxen. The whole unit is supported by standard-sized automotive-type wheels, bearings and tires.

The basic toolbar consists of a main frame with wheels, four tool clamps, two cart brackets and a combined box spanner and tommy bar. For complete versatility in plowing, hoeing, seeding, weeding, groundnut lifting and transportation, the following attachments can be fitted to the basic toolbar: a steerable toolbar, a pony moldboard plow, a ridger, four 13 and 25 cm. center shares, a seeder, a groundnut lifter and four spring tines for weeding. By putting the toolbar in the in-work position, a locally made cart platform can be mounted on the cart brackets and tongue.

The Mark IV, designed recently for the western African countries, has a very simple, straight lift mechanism operated from the rear. It was developed specially for all countries where animals are smaller and have insufficient strength to pull against excessive trash which may accumulate ahead of the soil working parts. With this mechanism the farmer operating the unit can, with slight effort, partially raise the coil-spring-assisted rear position of the toolbar. This will bring the cultivating implement

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[25] T.J. Willcocks, *Animal-Drawn Toolbar*, *ADT*. Overseas Liaison Unit, Technical Bulletin No. 2, (Silsoe, Bedfordshire, England: National Institute of Agricultural Engineering, January, 1969), p. 2.

[26] S.W. Cooper, "Mechanization on Small-scale Farms and Ox-drawn Implements, Part I", *Kenya Coffee*, Vol. XXXI No. 368, April, 1966, p. 1.

TABLE III. 3 APLOS ANIMAL-DRAWN TOOLBAR,[a] ATTACHMENTS AND PRICES 1968

Attachment	Mark II	Mark III	Mark IV Rear or forward control
Main frame assembly with clamp plate and angle and side link	$91.00	$94.00	$91.00
Cart brackets set with bolts	6.65	6.65	4.89
Ridger assembly	15.29	15.29	15.29
Plow-stalk and ridger-stalk stay	2.88	2.10	2.49
Tool clamps set	9.84	9.84	9.84
Steerable toolbar assembly	11.90	11.90	11.90
Tommy bar	0.76	0.76	0.76
Tool stalk set	7.96	7.96	7.96
Points set	1.50	1.50	1.50
13-cm. share set	1.68	1.68	1.68
25-cm. shares set	2.88	2.88	2.88
Bolt for points or shares set	0.84	0.84	0.84
Pony plow assembly	18.97	19.67	18.97
Groundnut lifter assembly	5.71	5.71	5.71
Canadian spring-tine assembly	7.82	7.82	7.82
Total Price (FOB factory)	$185.00	$188.00	$183.00

[a]John Darbyshire & Co. Ltd., 20 Nottingham Road, Somercotes, Derbyshire, England.

out of the ground, quickly clearing the trash and enabling the animals to move ahead.

This feature is very useful, when the ground has not been destumped and where the cultivation point has to be continuously raised out of the ground to avoid striking or hanging-up on obstacles. To permit the operator to remain seated, the machine is also equipped with a forward-control lever.[27]

Ariana ox-drawn toolframe is a multi-purpose generally wheelless toolframe, sold in western Africa and in East Africa, manufactured in Kenya by Heat Exchangers Ltd., P.O. Box 3070, Nairobi, Kenya. Originally developed by Jean Nolle, now affiliated with Mouzon Manufacturers, it is supplied to western Africa from France.[28]

The basic system sold in Africa consists of the main frame with skids; a reversible two-way, single-furrow moldboard plow; a set of three spring-cultivation tines; and duck-foot hoes. With this unit, all basic primary and secondary tillage and weeding operations can be performed. Ridger bodies and a steerable toolbar also are available. Approximate prices in western Africa are $193.00 for the basic system, $12.00 for the ridger body, and $39.00 for the toolbar. Tool prices for eastern Africa are given in Table III. 4.

As produced in Kenya, the main frame includes the chassis, two handles, two steel gauge wheels or two front skids and clamps, regulators and chain and a pulling chain. The frame is made of heavy, rectangular steel bars with a V-shaped nose. Hitch point, front-mounted skids and rear-mounted handles are adjustable for height. (Figure 3.12.)

A wide range of tool attachments, some described below, are available for the Ariana; they are also interchangeable with the French-made Tropiculteur and older Polyculteur wheel-type toolbars. All attachments clamp across the back of the rear-frame member except for the two-row seeder which clamps onto the side-frame. The clamps feature an eye-bolt tightener which can be turned with a short round iron bar. In addition, other tools are available such as disk seeder, leveler, roller, fertilizer distributor, and broadcast seeder. Technically, this is one of the best multipurpose animal tools, reasonably priced and widely distributed in Equatorial Africa; however sales to date are nominal.

1. The Ariana Uganda-type plow is a fixed single-furrow heavy-duty

[27] Instructor's Manual, *Modern Farming with APLOS Machinery*, (Somercotes, England: J. Darbyshire and Co., 1967).

[28] Jean Nolle, *Ariana Instruction Manual*, (mimeographed) (Seine-et-Oise, Paris: Mouzon Freŕes Societé, constructeur, A. Luzarches, 1965).

TABLE III. 4 ARIANA OX-DRAWN TILLAGE AND CULTIVATING EQUIPMENT[a] 1968

Ariana Ox-drawn Toolframe	Price
	dollars
Ariana Basic Unit	
Chassis	23.85
Handles with nuts and bolts	6.86 per pair
Regulator with bar and clips	4.86
Regulator chain	6.86
Skids (left and right) with pins	12.85 per pair
Clamps and screws	2.86 per pair
Pulling chain	3.29
Basic Set complete	61.00
Ariana Tools (Interchangeable with Tropiculteur)	
Fixed Uganda plow, complete	38.60
Reversible plow, holder and bodies, complete	83.60
Extension toolbar	13.72
Long spring tine (less blade)	4.15
Short spring tine (less blade)	2.57
Duck-foot blade, with nuts and bolts	1.00
Right, 1/2 duck-foot blade with nuts and bolts	1.29
Left, 1/2 duck-foot blade with nuts and bolts	1.29
Groundnut digger, body and blade	22.00
Chisel plow, body and blade	22.00
Spring-tooth harrow (107 cm.)	25.15
Disk harrow	172.80
Extra clamps	1.43
Spanner	3.14

[a]Price List No. 40 (1966) received from manufacturer, Heat Exchangers Ltd., Nairobi, Kenya, January 1968. All prices are approximate and FOB factory.

turning plow. It cuts a 23 cm. furrow and will plow to a depth of 18 cm. Depth is controlled by adjusting the height of the skid legs and the hitch regulator.

2. The Ariana reversible plow is a two-way single-furrow moldboard plow pivoting on a round beam. Individual right- and left-hand plow bodies, positioned about 80° apart, rotate and lock into vertical position to turn either a left- or a right-hand furrow. To turn at the end of fields, the plow and frame are lifted out of the ground by hand.

3. The Ariana simple ridging plow uses a different standard than the chisel plow. The extension wings are adjustable and the implement can be hitched for straight traction for primary tillage or for offset ridging or reridging. It can be used with the groundnut lifter mounted on the front crossbar as a ridge splitter for combination splitting and reridging. (Figure 3.12.)

4. The Ariana chisel plow, a heavy-duty soil-profile ripper for tillage deeper than ordinary plowing, has a single-beam body and blade. The beam is equipped with a vertical body about 6 cm. wide and 30 cm. deep. It can be used to break plow hardpan or for trash mulch tillage of semi-arid lands subject to wind and water erosion.

5. The Ariana cultivator tines are individual heavy-duty curved-spring tines welded to a square vertical bar and mounted with standard clamps like those used for attaching the front skids. Replaceable cultivating and hoeing teeth are bolted to the bottom and include a regular duck-foot blade from 10 to 18 cm. wide and right- and left-hand duck-foot blades from 10 to 14 cm. wide. Both a long and a short spring tine are available. When vegetation does not need to be turned under and soil tilth is good, these spring tines can be used as a heavy-duty field cultivator for primary tillage, besides hoeing row crops.

6. The Ariana extension toolbar allows extension of the working width of the tool frame, and permits double-row mounting and staggering of cultivator tines, when clamped to the rear of the main frame. This extends the cultivating width from 68 cm. to 120 cm. and permits mounting five or six cultivating teeth instead of only three on the main frame. In heavier soils, or under difficult conditions and deep tillage, more power is needed; either two large oxen will be required or two tandem pairs. Ox farmers in Kenya and Tanzania commonly use more than two oxen for primary tillage.

7. The Ariana spring-tooth harrow, a special seven-tooth spring harrow with a working width of 105 cm., is designed for secondary tillage, pulverizing and leveling of the seedbed, and covering of broadcast seed. It uses the short spring tines without replaceable teeth.

8. The Ariana groundnut digger, using the same beam and clamp attachment as the chisel plow, has a heavy-duty horizontal blade about 8 cm. wide and 35 cm. long. The unit is used astraddle the row with the beam offset to one side. Penetration and control are very good.

9. The Ariana disk harrow, a fixed-angle single-gang disk harrow, has three disks on each side throwing out, and a short spring tine for tilling the center. Equipped with 26 cm. disks it has a cutting width of 70 cm. A heavy tool and the most expensive attachment offered, it is probably one of the last tools the farmer would want unless he has a special need for it to prepare a nursery or truck garden seedbed .

10. The Ariana two-row seeder, originally supplied as a two-row disk-

Figure 3.12 The Nolle (French-designed) Ariana skid-type multi-purpose ox-drawn toolframe pulled by chain tongue hitch This implement is much less expensive than the wheel type units and the logical first step beyond the indigenous single-purpose plow to improved animal power. The ridging body attachment is shown. (AFR-138)

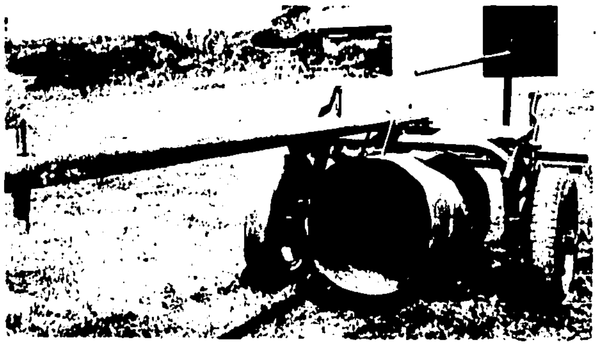

Figure 3.13 The Polyculteur (French-made) ox-drawn wheel-type toolbar A full barrel of water is easily attached by raising the tongue to hook back end of barrel and lowering tongue to hook a front U-latch to the barrel rim. The imported wheel type multi-purpose toolbar costs over twice as much as the skid type or about $430. (AFR-139)

type seeding unit, is patterned after the A. H. Engineering Co. seeder made in Soroti, Uganda. It may still be available. One disadvantage of the rolling-wheel seeder is its small capacity and variability in planting depending upon the amount of seed in the chamber. A weighted press-wheel firms the soil around the seed after planting. While no cost was given for the complete unit, the price of one basic A. H. Engineering Co. seeder unit for attachment to an ox-drawn toolbar is about $30.00.

Polyculteur ox-drawn toolbar, like the NIAE model, is a tool carrier mounted on roller bearing rubber-tired wheels. While it is much more versatile and expensive, it uses the same tool attachments as the Ariana toolframe. The basic unit, comprising the main frame, wheels, spring tine attachment and moldboard plow lists for approximately $300. A cart body is available to mount on the carrier for about $44. An extension toolbar with mechanical lift can be added to increase its capacity and utility.

The Tropiculteur ox-drawn toolbar is one of the most sophisticated of the animal-drawn multi-purpose toolbars. This is an improved model of the Polyculteur modified to fit East African conditions.[29] The basic unit, including a hand lift, steerable toolbar and larger cart body, lists for about $643.00 at the factory. The tool attachments are similar to those used with the Ariana toolframe. It also features a special built-in device to lift and carry a loaded 200-liter drum. (Figure 3.13.) It is recommended to African farmers by agricultural officials and over two hundred units have been sold in East Africa.

The Moroccan multi-purpose toolbar, an animal-drawn toolbar on sled runners with interchangeable tools for primary and secondary tillage, and for seeding has been developed by the Agricultural Engineering Service of Morocco. Acceptance, sales, price and distribution are not known but its design could be used for improvement of tools in Equatorial Africa.

Two multi-purpose tools were developed through an FAO project for Libyan small cultivators. The improved breaking plow incorporates an exchangeable plow share, weeding sweep, double moldboard and ridging body. A new multi-purpose cultivator for arid regions has detachable crossbars, tines, sweeps and ridging or hilling moldboards. It has possible use in arid equatorial regions.

The Arara ox-drawn multi-purpose cultivator is manufactured near Dakar, Senegal by the Société Industrielle Sénégalaise de Constructions Mécaniques

[29] Jean Nolle, *Le Tropiculteur, Owner's Manual* (Paris: Mouzon Tropiculteur, 1965).

et de Matériels Agricoles (SISCOMA) under license from its French parent company.[30] The unit comes in four versions for groundnut lifting, cultivating, plowing and ridging. The basic frame consists of a heavy, rectangular, steel box-beam to which various components are bolted on the rear. On the beam front a square socket is welded into which slides the arm of the head wheel for depth adjustment. A five-position hitch plate for the pulling chain forms the front of the beam. Bolted on the rear is a welded V-shaped handle assembly which can be raised or lowered 10 cm.

1. The groundnut lifter consists of a vertical shank of rolled steel fasten y two bolts to the frame. Three different-sized wing lifters are available with widths of 20, 30 and 50 cm. Total weight of the lifter is 23 or 24 kg.

2. The Arara Canadian hoe has three spring-tine blades with replaceable points of either shovel- or reversible-teeth design. The front tine is fixed, but a parallel-arm mechanism can be cranked forward to widen the horizontal distance between the two rear tines or backward to narrow the tilling width from 22 to 17 cm. The cultivating unit fastens to the beam with four bolts just behind center and its total weight is 35 kg.

3. The Arara moldboard plow is designed for a pair of oxen. Three different furrow widths are available: 15, 20 and 25 cm. weighing 24, 27 and 36 kg., respectively. The plow bodies are interchangeable and attach to the standard with two bolts. The one-piece share, moldboard and landside heel units are replaceable. A traction regulator adjusts each plow to overcome sidedraft and obtain correct line of draft.

4. The Arara ridging plow comes in three models. Two models have fixed wings of 25 cm. and 35 cm., weighing 22 to 23 kg., respectively. The third model has vertically-adjustable wings to throw the soil wider or higher. It weighs 28 kg. and features a replaceable, reversible point.

The Unibar ox-drawn toolbar, the latest entry in the multi-purpose animal-drawn implement line, is made by Project Equipment Ltd., Newton Toney, Salisbury, Wiltshire, England. It is being imported into both western and eastern Africa. The unit is the simplest and lightest type toolbar, inexpensive and sturdy. Some models have small wheels and an adjustable handle which tends to loosen. Due to its compact size, it can be used between rows in tall crops like maize, guinea corn and sorghum. Its Y-shaped main beam serves as a single-row cultivator, ridger and weeder

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[30] SISCOMA, *Multiculteur Passe-Partout* (license Arara).

to control yield-reducing weed growth in medium and light soil. Its development was aimed at bringing the benefits of mechanized cultivation to the small farmer at a price within his means.[31] (Figure 3.14.)

1. The Unibar cross-tying share features a cross-tying share 50 cm. wide designed to weed the furrows of ridged crops, while at the same time forming dams at intervals. The cross ties impound rain from occasional downpours until it soaks into the soil. One advantage of using oxen is that they can step over existing cross ties, and cultivation can continue even though some water may have collected.

2. The Unibar ridge splitter was designed around the minimum tillage principle of splitting old ridges to prepare land for planting with the least man-hours and lowest cost. More than one pass may be required to open hard ridges but, in the last one, cross-tying can be done without an extra operation. For this system of ridge cultivation, only three attachments are required: a ridger body, a cross-tying share and the combination hoe and groundnut lifter blades. The ridger has a replaceable point, and a vertically and horizontally adjustable moldboard. The ridger is equipped with a rudder for better control, and tail pieces can be added to the moldboards for wider furrowing.

3. The Unibar moldboard plow is a 20 cm. single-furrow fixed plow used for farming on the flat. It features an adjustable moldboard which can be widened or narrowed to change the cut. For planting on the flat the attachments required are: moldboard plow, three- or five-tined cultivator and hoe/groundnut blades.

4. The Unibar cultivator and groundnut lifter uses the same offset blades in 20 and 25 cm. lengths for hoeing, weeding and groundnut lifting. They can be turned in or out from center to work over or between rows. A 20 cm. duck-foot share, 6 cm. cultivator points and 13 cm. grubber points in sets of three or five are also available for weeding, as well as a 30 tooth rotary cultivator and clod buster.

5. The Unibar seeder is a one-row seeder for maize, sorghum, guinea corn and millet. It can be equipped with a separate fertilizer unit.

Three different combinations are recommended in Tanzania:

1. For farming on the flat the basic unit consists of the main frame, skids, cross shafts, cultivator points, rotary cultivator and 15 cm.

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[31] *The Unibar Animal-drawn Tool Frame*, (Project Equipment, Ltd., Newton Toney, Salisbury, Wiltshire, England, 1967)

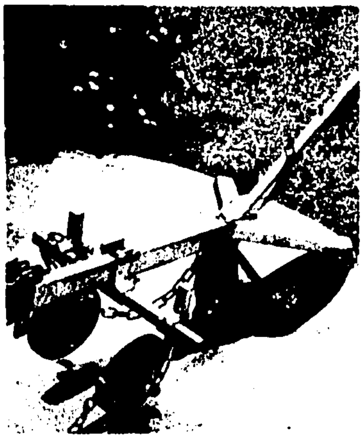

Figure 3.14 The Unibar (English-made) multi-purpose animal-drawn toolbar equipped with ridger attachment V-bars in rear are for attaching cultivator shovels or other attachments. Unlike most toolbars this tool is narrow enough to pass between rows of tall growing crops such as maize, millet and sorghum. (AFR-273)

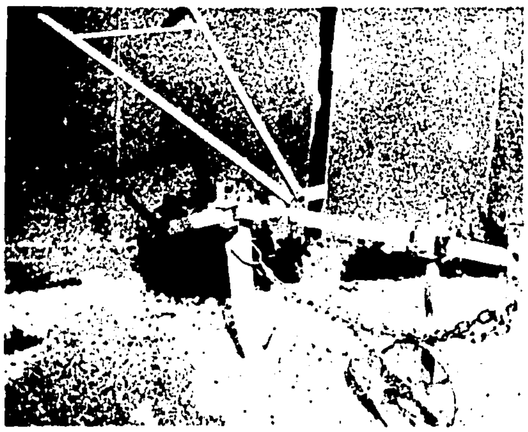

Figure 3.15 Hoe Sine 7 (French-designed) small tool carrier with a groundnut lifter attached Two oxen are required to pull this tool manufactured by SISCOMA factory in Senegal. Various attachments are available for plowing, cultivating, furrowing, fertilizing, ridging, weeding and groundnut lifting. (AFR-295)

moldboard plow. For planting, cultivating and weeding, the unit lists for about $64.00. A single-row seeder costs an additional $45 without fertilizer unit.

2. For permanent ridge farming a basic set can do ridge splitting, weeding, cross-tying, cultivating and lifting groundnuts. The suggested system consists of the basic frame with wheels, skids, cross shafts, 15 cm. plow body, ridger body, cross-tying and weeding share, cultivating points and groundnut lifting blades. The approximate price is $76.00.

3. For both flat and ridge farming (including plowing, ridging, weeding, cross-tying, cultivating and groundnut lifting), the complete system consists of the basic frame, with wheels, skids, cross shafts, 15 cm. plow body, ridger body, cross-tying and weeding share, cultivating points and groundnut lifting blades. The approximate price is $109.00.

The hoe Sine 7 is a multi-purpose tool built by SISCOMA under license from Mouzon Frères, France and is designed for a small horse, donkey or ox.[32] It has a much lighter beam than the Arara and greater versatility than the Occidentale hoe. The T-shaped frame is supported by a head wheel in front and is steered by double handles. The T-bar at the rear carries most of the attachments except for the front-center standard for cultivators and weeders mounted ahead of the handles on the main frame. A variety of equipment can be attached, of which the Canadian hoe and groundnut lifter are the most popular. (Figure 3.15.) For prices of selected SISCOMA implements see Table III. 5. Available attachments are:

1. A flat, wide, V-shaped attachment for shallow weeding and cultivating in between narrow rows.

2. A set of two furrowing or listing bodies preceeded by a smaller flat V-sweep for weeding between the furrows.

3. A Canadian-type hoe with three spring tines and replaceable points. Two 16 cm. duck-foot tines or reversible chisel teeth are spaced as desired on the T-bar and one in front center.

4. A fertilizer distributor for use with the Canadian hoe before or after planting. A larger front wheel is used with a crank arm to operate the fertilizer agitator and feed mechanism.

5. A set of three rigid cultivating-shanks with grass or duck-foot shovels designed for narrower, deeper penetration.

6. A flexible spring-tooth finger weeder with two rows of teeth for

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[32] *Tropiculteur, la Houe Sine, Systeme Nolle-brenets Mouzon*, General Catalog, Attachments, Scheme of utilization and instructions (Paris: Mouzon Tropiculteur, 1966).

TABLE III. 5 ANNUAL PRODUCTION AND PRICES OF SELECTED SISCOMA IMPLEMENTS[a]

Agricultural Equipment by Trade Name	Price (1968) dollars	Number Produced Annually					
		1963	1964	1965	1966	1967	1968
Semoirs (seed drills)	44.40	32,172	18,000	12,000	13,230	13,000	15,702
Houes Occidentales (donkey or horse hoe)	25.75	15,000	3,324	6,003	16,031	17,353	13,372
Houes Sine (small animal hoe)	30.00	5,293	-	-	2,827	16,723	5,222
Souleveuses Arara (harvester)	34.55	2,006	1,008	1,000	703	600	447
Charrues (plows)	39.70	3,912	1,507	800	947	1,000	510
Charrettes Equines (horse carts)	108.80[b]	420	178	250	2,000	3,000	6,500
Charrettes Bovines (ox carts)	108 80[b]	-	831	230	-	-	400
Charrettes Asines (donkey carts)	90.40[c]	-	35	251	1,468	2,293	1,001
Souleveuses Firdor (harvester)	15.43	-	-	-	-	13,850	4,180
Houes Ariana (Ariana hoe)	141.50	-	-	-	-	404	88
Cracker Colin (Colin nut cracker)	506.50[b]	-	-	37	-	-	-
Houes Saloum (Saloum hoe)	n.a.	106	138	-	-	-	-
Polyculteurs (polycultivator)	n.a.	1,229	-	-	-	-	-
Epandeur d'Engrais Irho (fertilizer spreader)	n.a.	4,585	-	-	-	-	-
Moulins à Mil (millet grinder)	n.a.	250	-	-	-	-	-

[a]Information supplied by M. Martinetti, Manager, SISCOMA Factory (26 July 1968).

[b]Price as of 1964-65.

[c]Price as of 1966-67.

early weeding of very small plants.

7. A standard 15 cm. moldboard plow with replaceable landside and share.

8. A standard 30 cm. fixed-wing ridging plow with replaceable point.

9. A groundnut lifter with three different-sized symmetric winged blades 20, 30, or 35 cm. wide.

Haynes makes the following comments in regard to the possible market in Nigeria for the Sine 7 hoe.

> The fertilizer distributor is extremely simple, consisting of an oscillating finger over a hole. Whilst the application rate could be reduced from 150 lb. [68 kg.] per acre by using a smaller hole, this might lead to blockages with the granular superphosphate used in North Nigeria. Further, this type of distributor must of necessity be inaccurate and it is possible that it will not prove satisfactory in areas where economic responses are only obtained from a narrow range of application rates.
>
> Without an extension campaign, the market for these hoes is probably small, say 30 - 40 per year, but they are compact and could be imported without difficulty. Even the improved front wheel bearing of the SISCOMA version, however, might prove unreliable in sandy soil and supplies of spares and replacement hoe blades would have to be organized.[33]

The Occidentale hoe, a light-weight, simple tillage tool, was designed for use with one animal for weeding, cultivating, ripping and surface scalping. It adjusts easily and has interchangeable standards and shovels. Three teeth are used in all cases with one in front center and two in the rear adjustable from 35 to 83 cm. (Figure 3.16.) It may be used:

1. For heavy tillage with 15 cm. duck-foot shovels, the maximum width is 50 cm; total weight is 16.7 kg.

2. For regular cultivating with diamond teeth, the maximum width is 78 cm; total weight is 16.3 kg.

3. For ripping, the maximum width with pointed shanks is 45 cm; total weight is 16.1 kg.

4. For surface weeding with winged-center shovel and half right- and left-hand offset shovels, the maximum width is 83 cm; the weight is 16.5 kg.

Haynes makes the following comments on the Occidentale hoe:

> This hoe was recommended by CRA as superior to the

[33] D.W.M. Haynes, *Report on Visit to Senegal*, Papers on Agricultural Engineering in Northern Nigeria (Samaru, Nigeria: Ahmadu Bello University, Institute for Agricultural Research, 1964), p. 5.

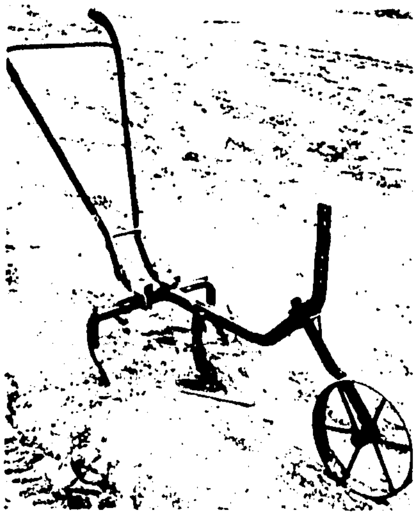

Figure 3.16 Occidentale (French-designed) multi-purpose animal-drawn hoe The implement's light weight permits it to be pulled by a single donkey, horse or ox. It is versatile, relatively inexpensive and recommended by the Bambey Centre for Agronomic Research in Senegal. (AFR-311)

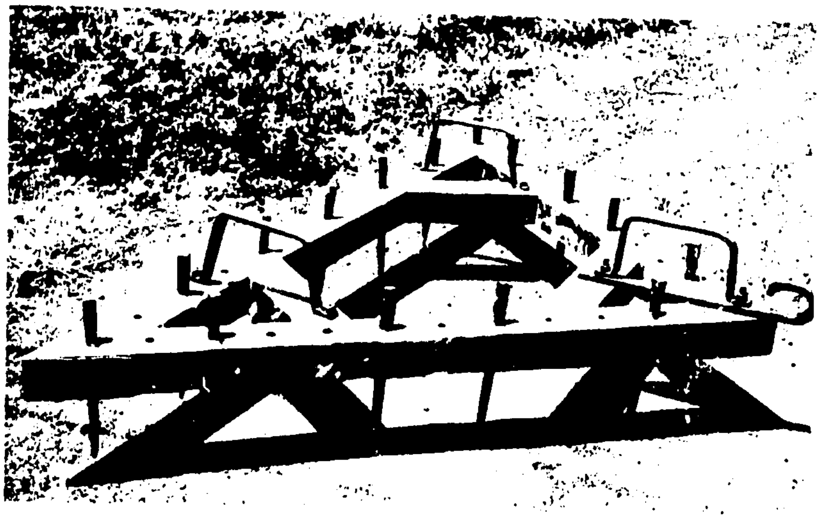

Figure 3.17 Tanzania: Triangular spike-tooth harrow This rugged and simple wood frame harrow can be easily fabricated from iron rods and timber. Undersize holes in the frame permit the peg teeth to be driven down to proper length as they wear off. It has skid blocks on the top so that it can be turned over for transport. (AFR-541)

more-recently introduced Sine 7. It is lower than the Sine 7 and might be more easily controlled on flat land but would be of no practical use at all on ridges. No other attachments (fertilizer box, ridger, etc.) are available for this single-purpose implement which costs about the same as the multi-purpose Sine 7. Unless it proves markedly superior on flat land, there would be little point in importing the Occidentale hoe in preference to the Sine 7.[34]

f) Field Cultivators and Harrows These single-purpose tools, whether locally-made or imported, are most suitable for purchase by an animal-powered farmer who already has a plow. The primary purpose is seedbed preparation, clod-breaking and leveling. On light soils and self-mulching vertisols they can be used without plowing. They can also broadcast seed, break up soil crusts, control weeds and aerate pastures.

The Cossul spring-tooth harrow, being sold in Tanzania, is suitable for deep tillage work in ground with roots and stones. It can work to a depth of 12 to 15 cm. and the spring action loosens the sod for rapid aeration and drying. An angle iron frame on skids carries five to seven spring-tine teeth adjustable for depth. Power required is two oxen for a five- to seven-tine model selling for $26 to $29 and weighing 40 and 57 kg., respectively .

Hopfen further describes this tool:

> The teeth of this type of implement are made from spring steel, flat on section and very curved. Attached to cross-bars they vibrate as they progress through the soil. The cross-bars can be rotated through a small angle with a lever and thereby the hitch, and consequently the penetrating depth, can be regulated. Each spring has a renewable working point [on better harrows].[35]

The spike-tooth harrow, also sold in Tanzania, Kenya and Ethiopia, is a spike- or peg-tooth harrow. A multi-purpose tool, it can be used with two oxen for leveling after plowing, firming seedbeds, breaking lumps, covering seed and lightly breaking crusts for better germination in event of hard rains after sowing. Tooth angle is adjustable for penetration and runner pegs are used for transport. Three sizes are available with 18, 25 and 30 teeth, weighing 27, 33 and 51 kg. in turn. Prices in Tanzania are about $17.00, $25.00 and $34.00, respectively. Although one of the commonest implements for seedbed preparation in temperate zones, its use has not been promoted in Equatorial Africa. It could be locally-made with a horizontal wooden or iron frame with cross-beams to which rigid, straight or slightly-bent steel teeth or tines are

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[34]Haynes, *Report on a Visit to Senegal*, pp. 5-6.

[35]Hopfen, *op. cit.*, p. 66.

attached in a variety of ways. For smoothing tilled fields the implement is used upside-down with its teeth out of action. Hopfen cautions, "It is not very effective in arid zones where it tends to pulverize the soil too much."[36]

The local triangular spike-harrow, developed by the Tanzania Agricultural Machinery Testing Unit (TAMTU) after an Indian model, is a heavy wood-frame harrow, shaped like a triangle, using extra length metal rods driven through undersized holes. As they wear off, the rods are driven down to normal depth. The unit can be turned upside-down for transport on skid blocks. Construction is simple and any carpenter or craftsman can make one from simple drawings. The unit is 90 cm. on one side and 120 cm. on the other sides. Weight depends on size of wood frame but varies from 30 to 60 kg. Two oxen are required for power. (Figure 3.17.) Price is variable but should not exceed $15.

Many different versions of linked, loose-jointed harrows are made in various countries. Factory-made metal units are made with steel rods hooked together in links. They tend to flex with the ground surface and do less leveling than a rigid harrow. They are used generally for very light tillage, early weeding, seed covering and sometimes for spreading manure. Longer teeth on one side give two working depths. *A simple wood-bar flexible harrow was described by the Central Treaty Organization (CENTO) Traveling Seminar in Pakistan. It could be made locally in any country and, because of its good design, would be a welcome addition to most animal-powered farms for secondary tillage.* It is made of three or four beams linked together by attaching the top of the front beam to the bottom of the rear beam with short metal eye rods. This keeps the teeth vertical but permits flexible action to clear debris and pass over obstacles.[37]

Planting

Methods and timeliness in sowing strongly influence germination, seedling growth, need for and nature of subsequent weeding and ultimate yield. Seeds and seedlings must have good environment for rapid and sustained growth with adequate moisture, aeration, temperature and nutrients. Main methods of seeding are broadcasting, drilling and planting on upland soils and transplanting in lowland paddy fields.

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[36] *Ibid.*

[37] Central Treaty Organization, *op. cit.*, p. 117.

Hand Planting Operations

1) Tools and Practices

In Equatorial Africa, hand farmers use practically no mechanical device to distribute or place seed. On small fields, seed is manually scattered or dropped into prepared holes or furrows. On larger fields, it is usually broadcast by hand in an arc in front of the sower.

a) Broadcasting In broadcasting by hand, the only aids used are a basket, waist-sack or gourd to hold the seed. The average sowing width is 2 to 3 meters. The hand broadcast-fiddle used in Asia and the Far East, mentioned by Hopfen,[38] was not observed in use in Equatorial Africa; nor was the cyclone crank-operated hand-seeder commonly used in America and Europe for sowing cover-crops and grass seed. However, when used with a steady walk and a constant cranking speed, the cyclone seeder gives quite accurate distribution up to a width of about 8 meters and is a marked improvement over hand sowing.

In Ethiopia practically all seed is broadcast regardless of the method of tillage. In the highland areas it is sown just ahead of the fourth plowing. (Figure 3.18.) In the southern hoe-farming areas, small grain seed is manually scattered over the prepared ground. It may be lightly hoed over, trampled in by animals, or left for the rains to cover in the rough cloddy land. *Teff* (lovegrass) is traditionally trampled into the ground by driving animals over the field. Subsequent rains complete the job of covering but very small *teff* seed must be firmly pressed into the ground or rains will wash it away.[39]

In the large commercial farm area in the Setit-Humera plains of northwest Ethiopia the seeds of cotton, dura and sesame are broadcast by gangs of sowers after the land is prepared by tractor and disk-harrows. As many as 30 to 40 men advance across large fields. Since about one-fourth hectare can be sown per hour, about 60 hectares can be sown in an eight-hour day.

Selection and cleanliness of home-grown seed affect germination and weed infestation. Bengtsson says,

> The major part of the farmers (83%) declare that they clean their seed in order to obtain a better planting material . . . [with] a small basket which is shaken and by help of the

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[38] Hopfen, *op. cit.*, pp. 77-78.

[39] Bengtsson, *op. cit.*, p. 22.

wind, the weed seeds could be separated from the grain.[40]

The present seed rate among farmers is much higher than that proven best in CADU experiments and trials in Ethiopia. See pp. 2-210 and 2-212.

In other parts of elevated eastern Africa, small grains and oil seeds are broadcast by hand farmers and covered primarily by hoeing. The large, commercial wheat areas are highly mechanized and most grain is sown with tractor-drawn seed-drills. Maize, the staple food, is planted in hills with a hoe; but in a few instances it is broadcast.

Hand farmers in Ghana, Nigeria, Ivory Coast, Senegal and Gambia, in western Africa, raise few small grains and consequently seldom use the broadcast method. Some rice is raised on uplands in animal-powered areas and in the wet valleys with supplemental irrigation. The Far East method of transplanting seedlings in paddy fields by hand is generally followed for irrigated rice. On most upland fields, the rice is sown by tractor-drawn seed-drills; where sowing is done entirely by hand, it is broadcast or dribbled into shallow furrows.

b) Hill-Planting Most hand farmers plant large seeds by placing a set number in hills, mounds or ridges. In shifting agriculture and minimum tillage cultivation holes are dug in cleared, and often burned-over, ground in a random manner with a hoe or planting-stick. The entire area is seldom dug up, but only the ground around the hill tilled for a diameter of 15 to 20 cm. In settled agricultural areas, the land is generally worked completely to prepare beds for planting seeds, root-stocks or seedlings.

In southwest Ethiopia, the Anuak and Nuer peoples raise maize and sorghum. Their method of hand-planting maize and sorghum is discussed in Chapter II.

Van Beyma, an agricultural missionary with the American Presbyterian Mission, has worked with the hand-cultivators in southwest Ethiopia to develop a planting-stick for hill-planting. The common hoe has been modified by replacing the solid handle with a hollow bamboo tube and cutting an opening in the side of the blade 5 cm. from the bottom. In operation the blade is jabbed into the soft ground and moved back and forth to form a wedge-shaped hole, so seeds dropped down the tube fall out the blade opening.

In Kenya and Tanzania and other parts of eastern Africa, no data were obtained on hand-planting methods or rates. In general, however, the

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[40] *Ibid.*, p. 21.

Figure 3.18 Ethiopia: Broadcast seeding Hand seeding in and between plowed guide rows which will be completely plowed to cover the seed. This results in many seeds being buried too deeply and some not covered at all giving spotty and thin stands. Seeding rates are usually double those required with more scientific practices. (AFR-544)

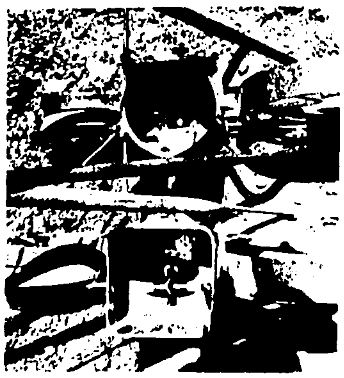

Figure 3.19 Technohac (Israeli) vegetable and cotton seed hand-wheel planters This type of mechanical seeder can make the hand- and animal-powered cultivator more efficient by saving seed and reducing subsequent thinning and weeding operations. The upper seeder can handle vegetable seeds, sugar beets and onions, the lower seeder undelinted cotton seed. Combined in pairs the seeders can be pulled by animal power or used singly by pushing with manpower. A share opens the furrow and another covers the seed before a split roller firms the soil over the sown row. (AFR-538)

hand farmer digs up the ground with the *jembe* hoes and plants maize and other large seeds in random-spaced hills which may resemble rows. Row-planting is more common in Kenya and Tanzania, following the example of commercial and European farms. Nearly all annual and perennial export crops are planted or drilled in rows. Rice and cotton are recent crops introduced with row-planting techniques.

In Ghana, Nigeria, Ivory Coast and Senegal, in western and central Africa, some root crops like yams, cocoyams, and cassava are planted in mounds. The soil is laboriously piled in heaps 30 to 60 cm. high and about one meter apart with the *garma*, a type of hand-plow. The seed-tube is inserted 15 to 20 cm. below the mound top and the mound often is capped with a piece of sod or large clod to help control erosion.

In Nigeria, Shambaugh says:

> In order to efficiently utilize the farmer's hand-labor, planting and thinning is done by hand. Due to the speed at which a farmer can plant by the heel-and-toe method, following the previous operation, a mechanical planter cannot be justified under the present conditions. One, however, can be readily attached to the tool-bar unit when it becomes desirable.[41]

c) Row-Drilling and Planting Drilling is the operation of placing seeds in shallow furrows cut in the seedbed by hoes, cultivator teeth, disk-openers or special furrowing and marking devices. Very few hand farmers habitually plant seeds in a line. *The introduction of cash crops and improved practices supported by marketing agencies and extension services gradually is persuading hand farmers to adopt row-planting.*

Surprisingly, seed-drilling was common practice in Mesopotamia, India and China for many centuries before the western world began to realize its importance. Hopfen says, "The Sumerians were the first to seed their grain in rows with a seeding-tube connected to a plow, a method still used in some eastern countries."[42] Modern mechanical hand planters recently introduced into eastern Africa are shown in Figure 3.19.

In southwest central Ethiopia, under influence of the Jimma Agricultural School, some hand farmers are planting maize, sorghum, broadbeans, and chickpeas in rows. Hills are aligned, and sometimes furrows are marked with hoes and the seeds dropped in by hand one at a time and covered by hoeing or pushing dirt over the seeds with the feet.

In Kenya and Tanzania, the African hand farmer tends to copy the

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[41]T.J. Shambaugh, Jr., *Mechanized Assistance to Hand Farming*, Special Report No. 68-9, (mimeographed) (Maiduguri, Nigeria: USAID, November, 1968), pp. 5-6.

[42]Hopfen, *op. cit.*, p. 78.

successful European farmer. The farmers' training-schools and settlements also stress row-planting so that many farmers, and their wives who raise most of the food-crops for home consumption, are now row-conscious. In western Tanzania and Kenya around Lake Victoria, some ridging is done by hand to conserve moisture and prevent erosion. Furrows and ridges formed by hand-hoes facilitates row-farming practices. Seeds are generally planted in hills in the middle of one meter ridges and on the sides of larger 1.5 meter ridges making a double row. Groundnuts, cotton, maize, sorghum and beans are planted on ridges. The agricultural research stations developed a system called tie-ridging in which cross-ties are put across the furrow every three to four meters to impound and hold the water during heavy rains.

In Ghana and Nigeria (and occasionally in other West African countries), extensive use is made of ridges for planting groundnuts, yams, maize, sorghum, millet, guinea corn, and vegetable crops. The ridges are made with the hand-hoe; generally 5 to 10 seeds are planted in each hill about 70 to 100 cm. apart. Tie-ridging is also practiced to some extent to conserve moisture and prevent run-off. In Senegal and Ivory Coast, upland rice is dribbled into furrows by hand and covered with the foot, partly because ridges do not hold up in the sandy soil. (Figure 3.20.)

While ridging has many advocates, some agriculturalists question its practice because of weed control problems and soil erosion losses. Shambaugh states that "After five years of mechanical cultivation of crops on both the flat and on ridges, we can see no advantage to ridge-farming [in northeast Nigeria]. In flat farming cultivation practices are simpler and easier and weed control is better."[43] Evidence from this area suggests that erosion losses from ridges may be more serious than previously thought. Thus, specific area research is needed to determine the value of ridging in localities where it is currently practiced.

2) Power Required

In hand-broadcasting, planting in hills, or dropping in furrows, sowing is relatively easy. Broadcasting is normally done by men while dropping of seeds into hills or furrows and covering is usually done by women and children.

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[43] T.J. Shambaugh, Jr., *Bornu Complete Tillage Machine* (mimeographed) (Maiduguri, Nigeria: USAID, October, 1968), p. 1.

Figure 3.20 Senegal: Row seeding rice by hand The simple process of marking rows or providing multiple furrows in the last tillage operation permits more efficient methods of inter-row cultivation for weed control. It also encourages use of improved varieties, fertilizer, disease and insect control, adoption of more efficient tools and use of improved power. Row seeding and weed control are perhaps the most important steps to improved farming practices initiated at very low cost. (AFR-539)

3) Time Required

In hand-broadcasting, Bengtsson determined that it took one person about one hour to sow one-fourth hectare by hand, or about four hours per hectare. The covering operation was not measured separately.[44]

a) Hoe Covering With the digging or weeding hoe, it takes many man-hours to cover broadcast seed. Using a work capacity of 100 to 150 $m.^2$ per hour for light-weeding by rectangular hand-hoe, manual covering takes from 67 to 100 hours per hectare or from 8 1/2 to 12 1/2 man-days. By using 8 to 12 people, one hectare could be covered by hoe in one day.

b) Livestock Trampling If livestock are available, they can be driven over the field sufficient times to trample in the seed. At 1.6 km. per hour, it would take a single animal about 10 hours to cover 0.4 hectare walking over 0.61 meter strips. In actual practice in Ethiopia, the time spent is considerably less but the coverage can be effective since there is a lot of scuffing and trampling by different sizes and weights of animals.

c) Brushing with Branches This method can be quicker than hand-hoeing. Walking at 0.8 to 1.6 km. per hour and dragging or swishing a branch over a 120 cm. swath, it takes a man five to ten hours per hectare, or four men 1 1/4 to 2 1/2 hours per hectare. Brushing is limited to fairly flat fields since coverage is very light and heavy rains can float

[44] Bengtsson, *op. cit.*, p. 24.

and wash away the loose soil and seed.

d) Planting in Hills In hill-planting maize in southwest Ethiopia it took two people (a man digging holes and a woman planting seeds) from 2 to 8 days to plant one hectare, depending on whether they were fast or slow. Sorghum-planting was slower, ranging from 10 days to 33 1/2 days per hectare for a fast and slow farmer, respectively. The average farmer planted one hectare of maize in 5 days and sorghum in 22 days.

e) Dribbling in Rows In hand-dribbling into prepared furrows, a man and woman or older child can sow about 13.5 m. of row per minute moving at 0.8 km. per hour. If the furrows were 30 cm. apart for rice, wheat, flax etc., it would take two people 41 hours or about 5 days to plant and cover one hectare. If the crop rows were spaced 60 cm. apart instead of 30 cm., row-planting of maize, sorghum, millet or guinea corn could be accomplished in 4.4 man-days.

Shambaugh's work indicates that hill-planting by hand in pre-marked rows can be very fast and inexpensive. A hand farmer took an average of only 6.7 man-hours to plant a hectare of guinea corn and 14.1 man-hours to plant a hectare of groundnuts. In these examples the farmers' labor is valued the same as labor he would have to hire.[45] (Table III. 6.)

In a comparison test in northern Nigeria in 1958, Haynes reported hand-planted groundnuts required 28.7 man-hours and hand-planted guinea corn 39.5 man-hours per hectare.[46] Evidently different methods were used than employed in Shambaugh's work.

TABLE III. 6 HIRED HAND LABOR REQUIRED TO PLANT SELECTED CROPS: NORTHEASTERN NIGERIA 1968[a]

Date	Crop	Area	Total time	Hours/	Cost/hectare[b]
		hectares	hours	hectare	dollars
May 20-21	Millet	1.21	10.0	8.3	0.89
June 12-13	Guinea Corn	1.21	8.0	6.6	0.74
June 15-16	Groundnuts	0.81	11.3	14.0	1.56
June 26	Cotton	0.81	4.5	5.6	0.62

Note: The primary tillage was performed by a tractor field cultivator, developed by Shambaugh, in which two 51 cm. wheat-land-sweeps removed any weeds in the row and marked the two parallel rows for hand-planting by heel-and-toe method.

[a] Figures abstracted from Shambaugh, *Mechanized Assistance to Hand Farming*, Special Report 68-9, p. 7.

[b] Computation based on $0.11/hr. actually paid to hired labor in this area in 1968.

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[45] T.J. Shambaugh, Jr. *Mechanized Assistance to Hand Farming*, Special Report 68-9, (mimeographed) (Maiduguri, Nigeria: USAID, 1968), p. 7.

[46] D.W.M. Haynes, *A Brief Review of Mechanization Experiments in Northern Nigeria* Papers on Agricultural Engineering in Northern Nigeria (Samaru, Nigeria: Ahmadu Bello University, Institute for Agricultural Research, 1964), p. 12.

f) Planting in Mounds In Ghana and Nigeria no records were obtained on time and work rates for making and planting in mounds. One mound per square meter equals 10,000 mounds per hectare. If it takes a man five minutes to make one mound (12 per hour), it would take 833 man-hours or 104 man-days to mound one hectare. When smaller mounds are made taking only three minutes per mound (20 per hour), it takes 500 man-hours or 62 1/2 man-days per hectare. If actual planting of mounds takes 15 to 20 seconds each, or three to four per minute, it takes 5 to 7 man-days to plant one hectare.

4) Skill and Management Required

Special skill is not needed to plant seeds, but since seed is the only item hand- (and most animal-powered) farmers purchase, it constitutes a vital part of the budget. The farmer himself, therefore, takes charge of the field sowing of broadcast crops. Women usually plant garden crops to be consumed by the family.

Leander reported that in Ethiopia "the only farm input of significance in terms of value was seed . . ., 17% of the total crop production [cost] was used as seed, ranging from 12% as the lowest and 27% as the highest."[47]

Timing of planting always is regarded as critical for maximum yields. In Ethiopia, the Institute of Agricultural Research reported that "early sowing by late June or early July at the time of the onset of the rains seems to be one of the necessary prerequisites for high yields. . . . Likewise for the dry season starting in October, early sowing is essential."[48]

Good seed selection and proper cleaning insures not only good germination and growth characteristics, but also reduces weed competition and subsequent weeding costs. Bengtsson reported seed purchased in the market normally contains 10 percent impurities, seed selected and cleaned by the farmers themselves only about 4 percent, and seed furnished by the Kulumsa Seed Multiplication Farm less than 1 percent.[49]

On non-irrigated upland soils, timing of planting depends primarily on the unpredictable rainfall pattern. In some regions, small spotty rains precede the big rains and permit the start of land preparation without being sufficient to sustain seedling growth. Crops are planted toward the end of the small rains or at the beginning of the major rainy season. In years of unusual or deficient rainfall, the farmer must be ready as soon as possible and use his best judgment based on experience and knowledge. Nevertheless, partial replanting often is necessary.

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[47] Leander, *op. cit.*, p. 92.

[48] Imperial Ethiopian Government, *Progress for the Period February, 1966 to March 1968*, *op. cit.*, pp. 6-9.

[49] Bengtsson, *op. cit.*, p. 18.

In regions with distinct wet and dry seasons and limited growing periods, land preparation is critical for annual crops. For the hand farmer the arduous work for an extended period can be offset only by hiring extra labor, if wages and workers are available, or by finding some way to minimize seedbed preparation. Possible methods are: burning and planting directly in bared ground; splitting old ridges to form new ridges without plowing; plowing once or twice instead of 3 to 4 times; or using improved field cultivators in place of plowing with upgraded power and implement systems.

5) Costs Involved

Even at the very low wage rates common in Equatorial Africa, labor costs for hand power can be expensive. Broadcasting seed takes about four hours per hectare, but covering without help of additional animal- or engine-powered tools can be costly, especially if extra labor must be hired for planting.

a) Covering Broadcast Seed by Hoe In Ethiopia, hired hand labor costs about \$0.40 to 0.60 per man-day. To cover one hectare by hand hoe at the lowest work rate of 100 to 150 $m.^2$ per hour would cost \$3.35 to \$5.00; plus the cost of broadcasting of \$0.20 to \$0.30 for half a day for a total of \$3.55 to \$5.30 per hectare.

b) Covering Broadcast Seed by Trampling Livestock trampling is an inexpensive way of covering seed providing there are sufficient animals, and the soil moisture and tilth conditions are favorable. Ethiopian herds are well trained for threshing grain in a circle. Moczarski reported seeing a farmer driving his cows in circles as they moved across the field to trample in seed.[50] If a farmer and a helper spent only 4 to 8 hours herding cattle in trampling, the cost of covering a hectare would be nominal; perhaps 1 1/2 days' wages at \$0.40 per man-day, plus the cost of broadcasting at \$0.20 to \$0.30 for a total of \$0.80 to \$0.90 per hectare. There would be some wear and tear on the animals, but this could be minimized with rest and good pasture.

c) Covering Broadcast Seed by Brushing Covering by dragging a brush on fairly flat fields would take a man 5 to 10 hours per hectare working constantly. Two men working half the time could cover one hectare in 8 hours at a cost of 2 man-days or \$0.80 per hectare. The total cost, including broadcasting, would \$1.00 to \$1.10 per hectare.

[50] Moczarski, *op. cit.*, March, 1969.

d) Planting in Hills Hill planting maize in southwest Ethiopia, an average farmer and his wife take 5 days equal to 8 3/4 man-days (using Norman's labor equivalent for a woman equal to 0.75).[51] At $0.40 per man-day, this amounts to $3.50 per hectare.

Sorghum planting in southwest Ethiopia takes 22 days for a man and woman, equal to 38 1/2 man-days. At $0.40 per man-day, the cost per hectare is $15.40.

e) Sowing in Rows Dribbling seed in furrows 30 cm. apart by hand at 0.8 km. per hour takes two men 5 days or 10 man-days to plant and cover one hectare. At $0.40 per man-day, this would cost $4.00 per hectare.

f) Planting in Mounds If mounds are already made and then planted at the rate of 3 to 4 per minute, it would take 5 to 7 days to plant one hectare with 10,000 mounds. At $0.88 per man-day, planting would cost $4.40 to $6.16 per hectare.

In Table III. 7 is presented a summary of hand-planting costs as discussed in preceding examples, but with all labor costs left in terms of man-hours in order to obviate the difficulty of assuming an arbitrary wage rate.

Animal Planting Operations

1) Tools and Practices

The art of planting in rows and the use of an automatic mechanical seeding device is not a development of our modern agricultural society. As Hopfen points out:

> Seed drilling for many centuries was common practice in Mesopotamia, India and China before the western world began to realize its importance.
> Chinese seed drills generally have two or three seed-tubes. The ancient (possibly 200 B.C.) feed mechanism, still in use, shows there was a need for an automatic, reasonably selective and positive ejecting device on an implement already in use in those far distant days for drilling seeds in furrows.[52]

The three common methods of sowing seed are broadcasting, drilling and planting: techniques that may be described as random, metered, and precision planting.

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[51]The people of northern Nigeria where Norman conducted his studies are predominantly Muslim. Traditionally, after marriage women remain within the family compound; thus, Norman employed a second figure for agricultural labor unit equivalent of 0.00 for Muslim women above 15 years of age.

Norman, *An Economic Study of Three Villages in Zaria Province, 1. Land and Labor Relationships*, p. 9.

[52]Hopfen, *op. cit.*, pp. 78-79.

TABLE III. 7 SUMMARY OF AVERAGE TIME PER HECTARE FOR HAND PLANTING VARIOUS CROPS IN EQUATORIAL AFRICA

Planting Method	Crop	Planting Time	Covering Time	Total Time
		man-hours/ha.	man-hours/ha.	man-hours/ha.
Hills in pre-marked furrows	Cotton	5.7	-[a]	5.7
	Guinea Corn	6.7	-[a]	6.7
" "	Millet	8.2	-[a]	8.2
" "	Groundnuts	14.1	-[a]	14.1
Broadcast covered by animal trampling	Teff	4-6	12	16-18
Broadcast covered by brushing	Barley	4-6	16	20-22
Prepared mounds - planting stick	Yams	40-56	-[a]	40-56
Hills with hoe	Maize	40	30	70
Pre-marked furrows by hand and foot	Rice	60	20	80
Broadcast covered by hoeing	Wheat	4-6	67-100	71-106
Hills with hoe	Sorghum	176-308	-[a]	176-308

[a]Cost of covering included in cost of planting.

While broadcasting of cereal grains has been abandoned in most countries with advanced agricultural practices, it remains the most common method of sowing in Equatorial Africa where animal power is used. In Ethiopia maize and sorghum are still sown broadcast, in addition to wheat, barley, flax, sesame, *teff* and cotton. Because it does not insure the best conditions for germination and seedling development, sowing rates are generally much higher. Seed covering is a separate operation in the form of an additional plowing and the haphazard location of plants greatly hinders subsequent weeding operations by hand or animal power.

The uniformity of seed distribution accomplished on the move with mechanical devices depends mainly upon the accuracy of the seed-metering technique and condition of the seedbed. The main advantage of drilling is the creation of spaced rows which facilitates efficient weeding operations. It aligns and spaces the plants accurately in one direction and requires less seed. It permits greater capacity and speed with animal-drawn tools for inter-row cultivation and weeding. The technique of drilling seed during the last animal-plowing operation is still used in northern and eastern Africa.

Normally hills or holes are placed equidistant in uniformly spaced rows or ridges. When cross-checked and lined up in both directions on the flat, this permits mechanical cross-cultivation for the most efficient method of removing weeds between plants. Young plants or seedlings can be transplanted into prepared holes, as in Nigeria with sorghum and guinea corn; in Ghana with tomatoes and peppers; in Ethiopia, Kenya and Tanzania with cabbages and other vegetables.

In animal-powered farming areas in eastern Africa, planting of seeds is almost exclusively a hand operation. A few mechanical seeders are available but they have not been entirely satisfactory and their economic cost is hard to justify on small areas of mixed crops. By contrast, *in the Francophone countries of western Africa, animal-pulled seed planters have been highly promoted and are extensively used in Senegal, Mauritania and Mali.* In 1965 over 182,000 animal-drawn seeders were reported to be in use. (Table III. 8)

a) Broadcast Seeding The timing and procedure for sowing both field and garden crops for northwest Ethiopian highlands and lowlands described by Simoons is similar over eastern Africa wherever animal-power is traditionally used.

> The sowing of seed begins with the first rains, as early as April if the season is early, but more often in May or June. Farmers often sow another crop in September to take advantage of the late rains. Broadcast sowing is the preferred method of the Northwest. This work is done by the men. In some cases, after sowing such small-seeded cereals as *teff* and finger millet, the highland farmer drives sheep, goats, donkeys or cattle over the field to cover the seed, or he simply brushes soil over it with the branches of trees. More commonly, however, the plow is used to cover the seed after broadcasting. Planting of individual seeds is normally done in the highland only in the garden, and even there only for the seeds of certain plants, such as gourds and squash.[53]

In south central Ethiopia the animal-powered farmer uses a small, flat basket called a *kuna* to carry the seed. Held chest-high the sower throws out a handful of seed with about every other step. Sometimes the plowman marks a guiding furrow about every 3 or 4 m. for the sower to follow as he dispenses the seed. (Figure 3.18.) The present seed rate is almost double that proven best in experimentation.

> At present, farmers plant about 180 kg. of wheat and 165 kg. of barley per hectare while the optimal rate at Kulumsa is considered to be 100 kg. per hectare. This comparatively high seed

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[53] F.J. Simoons, *Northwest Ethiopia: Peoples and Economy*, (Madison: University of Wisconsin Press, 1960), Chap. 5 *passim.*

TABLE III. 8 CENSUS OF AGRICULTURAL EQUIPMENT IN SELECTED FRANCOPHONE COUNTRIES OF EQUATORIAL AFRICA AND MADAGASCAR 1965[a]

Machinery	Senegal & Mauritania	Mali[b]	Niger	Upper Volta	Ivory Coast	Congo	Cameroon	Central African Republic	Tchad	Madagascar	Total Year 1965	Comparison with Year 1957
Tractors	392	120	39	34	824	186	573	167	20	1750	4,105	5,200
Motorized cultivators	62	9	6	12	87	28	68	15	10	75	372	145
Combine harvesters	60	21	n.a.	2	14	15	n.a.	5	3	40	160	219
Plows, ridgers	5316	100000	650	2070	1000	124	10520	1600[c]	10700	46000	177,980	78,000
Hoes and weeders	40640	82000	1297	8792	250	n.a.	100	62	1347	400	134,888	5,800
Multi-cultivators Polyculteurs	5000	d	2000	10	80	10	20	n.a.	12	350	7,132	750
Seeders, planters	100000	82000	500	230	100	30	95	23	460	200	183,638	41,700
Carts, trailers	10500	500000	480	600	25	n.a.	1300	1200[c]	4400	40000[e]	108,505	13,800
Sprayers, dusters	4550	32000	310	1020	13300[f]	400	30000	2000[c]	2850	2500	88,930	16,150
Mills, grinders	n.a.	n.a.	2800	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	g	4,200
Decorticators:												
Coffee	n.a.	n.a.	n.a.	n.a.	1500	n.a.	1300	37	n.a.	n.a.	g	2,300
Groundnuts & rice	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	400	21	n.a.	n.a.	g	1,400

[a]Adapted from *Machinisme Agricole Tropical*, (Centre d'Etudes et d'Experimentation du Machinisme Agricole Tropical (CEEMAT), No. 19, July-September, 1967), p. 32.

[b]The Mali figures for animal-drawn equipment, sprayers and dusters include a program to be finished in 1968.

[c]Included is a BDPA (Development Bank) program in process of completion in the OUHAM region.

[d]Hoes, harrows and multi-purpose toolbar equipment included in the preceding item (82,000).

[e]A relatively large part of the cart frame is locally assembled.

[f]Includes about 2000 air pressurized sprayers carried on the back.

[g]Data incomplete.

> rate could be explained, however, as the seed is contaminated with weed seeds and inert matter up to percentage of 5-10 percent and still more sometimes. In addition, the plough will cover many seeds too deeply.[54]

Immediately after broadcasting the field is plowed to cover the seed. Teff, however, is covered with the help of animals.

b) Row Planting In western and eastern Africa, many animal-farm still plant by hand and foot.

In northern Nigeria and Ghana, animal-plow farmers normally plant by hand after plowing or ridging the land. Ridge planting is most common in Nigeria and, although used extensively in Ghana on the lighter sandy soils, the ridges tend to be smaller because they break down and erode under heavy rains. As a rule, animal farmers must wait until the rains begin before they can ridge. On previously farmed land, the popular technique is to split old ridges and then tie-ridge them to form small earth dams at intervals in the furrow. The planting is done with the heel-and-toe method on the ridge, with five to ten seeds planted in each hill every step or two.

In Gambia and Senegal, animal-plow farmers without seeders generally plant on ridges, although upland rice is planted on the flat. Moczarski says:

> On ridges, especially in sandy soils, the common method is to dig or poke a hole with a short handle hoe or planting stick, drop in the seed and allow the dirt to fall back in and firm it with the foot. Maize is planted on both sides of the three foot ridge about 1/3 meter apart while groundnuts and yams are planted in the center about 1/2 meter apart. Groundnuts are planted about three cm. deep and yams about 12 cm.[55]

In Kenya and Tanzania there has been a marked trend for hand- and animal-powered farmers to plant in rows on the flat, due to influence of European commercial farms, the introduction of cash crops like cotton, and the availability of government and private tractor-hire services. Furthermore, since maize is the basic food-crop of most of East Africa, it has been planted in hills by hand for many years. With the use of animal-power or the tractor-hire service for basic tillage, row planting is readily accepted because of the ease in following natural furrows made by the plow or disk.

Regular animal ridging is practiced around the Lake Victoria areas and

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[54] Bengtsson, *op. cit.*, pp. 23-24.

[55] Moczarski, *op. cit.*, February, 1969.

in higher rainfall area where cotton is grown. With hand seeding, crops are planted in rows and thinned in three weeks. Gibbons said the extension service in Tanzania has succeeded in doubling cotton area in the past five years.[56] The most critical area in cotton production is planting. The farms range from 1.2 up to 5 to 6 hectares.

Aukland says a hand farmer can only till, plant and care for 1.2 ha. of cash crops plus another 1.2 ha. of food-crops. Larger farmers are forced to use animal or tractor power for tillage. Planting is done on the ridge by hand, assisted by hoe, planting stick or foot.[57]

c) Plow Tube Seeders Simple animal-drawn seeders have been used for many centuries in southern and eastern Europe and in the Middle East, and probably were brought into northern and central Africa by Arab cultivators.

Farmers in the northern provinces of Ethiopia use a seeding tube on the rear of their spade-blade body Arab-type plows. During the last plowing, the plowman drops seeds down the tube into the furrow. The seed is covered by the soil as it rolls back into the cavity. Since the oxen walk slowly, the plowman can do a fairly accurate job of spacing crops by dropping a pinch of seed into the mouth of the hollow tube with every step.

This method is still used today by some ox-plow farmers in the lower Awash River Valley in eastern Ethiopia. Moczarski reports:

> In Assaita the traditional Afar farmers have grown maize for centuries. They use a seed tube on the back of an Arab-type breaking plow and a boy walks behind the plow and drops two seeds down the tube each time. The seed is usually carried in a gourd or small woven basket held in the hand. The desired spacing is about 30 to 36 cm. with rows about 50 cm. apart. The seeding is done on the second plowing crosswise to the first. Since crops are planted on recently flooded land there isn't time to plow more than once as the crop must be planted as soon as possible so it will mature before the land dries up.[58]

The multi-tube funnel seeder, an Indian-type multiple-tube seeder called *goru*, is patterned after the plow-seeding tube. On this simple machine 2 to 6 wooden metal-tipped row-marking shoes are mounted under a beam and slanted forward. Hollow seed tubes pass through each furrow-maker and discharge behind them with their tops connected to a common

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[56] W.D. Gibbons, Assistant Director, Western Region, Ministry of Agriculture, Mwanza, Tanzania, Personal Communication, October, 1968.

[57] J. Aukland, Director and Chief Research Officer, Ukiriguru Research Station, Western Tanzania, Personal Communication, October, 1968.

[58] Moczarski, *op. cit.*

funnel. In use, seed is placed in the funnel and trickles out each tube as the drill is pulled forward. By putting a small amount of seed in the funnel as the animals move, a rather constant discharge can be obtained. Care must be taken when more than three tubes are used, to be sure equal amounts of grain pass through each tube. This device is not commonly used in Equatorial Africa.

d) Mechanical Seeders In Francophone West Africa, the most popular animal-drawn seeder by far is the SISCOMA-made Super Eco, produced under license from Ulysse Fabre. The few mechanical seeders used by animal farmers in Ghana, are most likely the SISCOMA unit. In Nigeria, some seeders were manufactured at the Senafrica Factory at Kano, associated with the CFAO firm in Nigeria. Haynes said they "made large numbers of the same type of seeder that form the bulk of SISCOMA's production." The seasonal manufacture, method of distribution, and lack of support from the extension service apparently would not support a viable commercial enterprise. "The Kano venture was a failure and large stocks (probably over 150 seeders) remain in the factory yard (1964).[59]

In another report, Haynes said:

> Ox-drawn planters . . . tended to produce lower yields in early trials . . . but in a test of five makes in 1958 there was no difference in yield between machine-sown and hand-planted crops. . . . the Super Eco was considered the best and was manufactured in Kano with the ridge model, with fertilizer attachment, costing $70.00 in 1958.[60]

In eastern Africa, at least two companies made a simple mechanical seeder for the small farmer. The A.H. Engineering Works, Ltd., P.O. Box 280, Soroti, Uganda is still manufacturing a rolling-wheel-type seeder patterned after the Bentall from England. This seeder was developed at the special development section of the Department of Agriculture, and was turned over to the A.H. Engineering Company for manufacture. A larger improved model of the Bentall-type seeder overcame many old problems, but still does not accurately plant a variety of crops.

Stephens reports that a large number of the Bentall seeders were sold in Uganda but no precise figures were given on how many are still in use.[61] Brown also stated in 1967 they were still satisfied with the performance of the A.H. Engineering Co. seeder and would not adopt another unless it

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[59] Haynes, *Report on a Visit to Senegal*, Section II, Appendix P, p. 4.

[60] Haynes, A *Brief Review of Mechanization Experiments in Northern Nigeria*, pp. 11-12.

[61] Brown, *et. al.*, *Agriculture in Uganda*, *op. cit.*

ere cheaper and more efficient.[62] In Tanzania, small animal-drawn seed rills are being imported from India, but no record of sales or distribution s available. No animal-powered seeders are being imported currently into enya or Ethiopia.

The A.H. Engineering seeder is a single-row sowing device made of wo halves of a hollow disk-wheel. Hole sizes and row spacing can be aried by locking interchangeable sliding gates in selected positions on he rim. (Figure 3.21.) Seeds are loaded through a side hatch into the enter cavity and as the wheel rolls forward around a fixed internal gitator, seeds refill openings in the perimeter and fall out the seed-ates. The openings are set i side the rim to avoid bloc!.age by dirt or ticky soil. A furrower blade opens a trench in front of the wheel and scraper pulls dirt over the furrow after the seeder passes. The .H. wheel-seeder is priced at $30.00 per unit plus $11.00 for a seeder rame, but is very simple with few wearing parts.

The Bentall wheel seeder is basically the same design as the A.H. eeder. (Figure 3.21.) Its capacity is limited, requiring frequent filling, nd variations occur in seeding rates from full to nearly empty. A single entall Unit sells for $21.00.

Various seeding units were tested by Cooper, who commented on the ollow-concave wheel-seeder used for sowing maize:

> It had little to commend it for planting maize. The wedge shape or flat grades of seed caused frequent jamming and intermittent delivery of seeds even in good conditions and on smooth surfaces; three different sizes of wheel were tested but in all cases the drive was not positive, the quantity of seed in the hopper had a marked effect on the seed rate, there was a wide difference between the 1/2 to 1/4 levels, loadings of more than 1/2 and below 1/4 full were not practicable. Speed of travel also produced a wide variation on seed rate, up to 53 percent reduction occurred from 0.5 to 2.5 miles per hour [0.8 to 4.0 km. per hour]. Soil adhering to the wheel perimeter also hindered seed delivery. The depth of planting to a large extent depended on the soil conditions; in loose dry conditions the soil trickled into the furrow before the wheel dropped the seed.[63]

The Super Eco seeder, identical to the French model of the same name, s a well-built all-metal machine with ground drive. Two 45 cm. diameter heels power the seed plates and seed pickup reel to control the spacing

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[62] W.T. Brown, "Report of Special Committee on Agricultural Engineering", *inutes of a Meeting of Specialist Committee on Agricultural Machinery*, mimeographed) (Tenguru, Arusha, Tanzania: Northern Research Center, ctober, 1967), p. 23.

[63] Cooper, "Mechanization on Small-scale Farms and Ox-drawn Implements, art I", *Kenya Coffee*, *op. cit.*

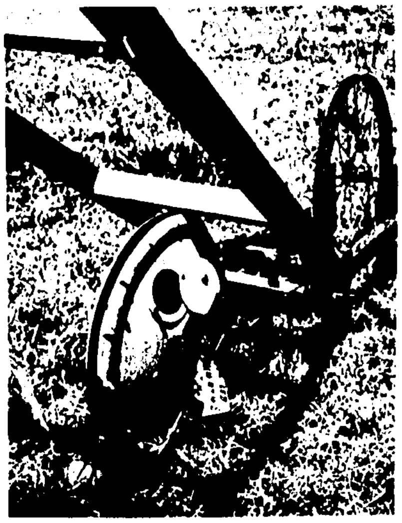

Figure 3.21 <u>A simple steel wheel seeder</u> Patterned after the Bentall seeder made originally in United Kingdom and Uganda, the A.H. seeder wheel is made by the A.H. Engineering Works, Soroti, Uganda. The seeder shown is for manual operation but units could be combined to make larger animal-drawn seeders. Removable and adjustable gates in the open rim of the wheel, permit different seeding rates and various types of seeds to be sown. (AFR-126)

and the number of seeds ejected into the furrow. (Figure 3.22.) A star or plate rotates slowly, forcing single seeds out of the hopper. Pulled by one animal, usually a horse or donkey, a knife blade slits open a furrow which is further enlarged by the seed tube. Two duck-foot shovels, one on each rear side of the seed tube, roll dirt into the furrow to cover the seed and a concave press-wheel firms the soil. An adjustable marker swings right or left to mark the next row.

While seeders are designed for sowing on the flat they also can sow on top of a wide ridge or bed, or into a furrow. For small grains two seed plates are available: one with 14 holes plants at 30 cm. intervals and a second with 24 holes provides 18 cm. spacing. For the latter, it is recommended that the rows be at least 60 cm. apart to permit weeding with an animal-drawn hoe.

For large seeds such as groundnuts and hill-planted crops such as maize and sorghum, finger-star-reels are used. A three-arm reel plants at distances of 130 cm., a four-arm reel is used for small millet and *sagon* at 100 cm. spaces, and a five-arm reel is used for large millet, sorghum and

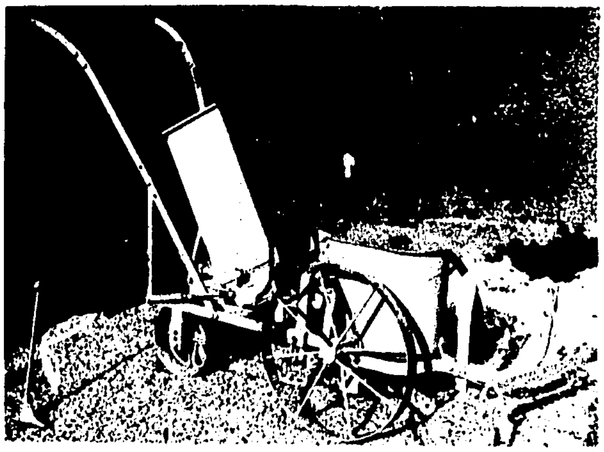

Figure 3.22 SISCOMA (French-designed) animal-powered (ox, horse, donkey) seeder with fertilizer attachment Farmers like this one-row seeder, but say that a two-row unit is too heavy. It is manufactured by the SISCOMA farm machinery factory near Dakar, Senegal. (AFR-294)

bassi at 80 cm. Other plates are available to plant maize, rice, *niebe* and cotton. The machine reportedly can plant undelinted cotton seed.

Haynes investigated the possibility of importing the Super Eco into Nigeria and reported:

> The seeder is successful in Senegal because it increases yields and because planting was previously a labour bottleneck. It appears to be generally agreed that planting is not a bottleneck in northern Nigeria and that planters costing \$42.00 - \$58.00 are an expensive luxury. The Super Eco seeder has been tested at Samaru and, if the Ministry of Agriculture wishes to carry out an extension campaign in the extreme north, it is probable that adequate supplies can be obtained in Kano more cheaply than by importing from SISCOMA.[64]

The seeder also can be equipped with a fertilizer distributor as shown in Figure 3.22. The agitator and metering wheel are driven by a chain drive from a gear on the seeder drive shaft. The fertilizer is dispensed on both sides of the row at a rate of 168 kgs. per hectare (suitable for Senegalese conditions), but different sprockets can vary this rate.

The Cossul ox-drawn seed drill is a new animal-drawn seed drill imported into East Africa from India which uses a fluted feed-roll for seed

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[64]Haynes, *Report on a Visit to Senegal*, p. 5.

metering and disk-furrow-openers. Rows are adjustable from 15 to 25 cm. At present, only a three-row model weighing 94 kgs. is being imported, but a five-row unit weighing 110 kgs. also is available. This drill is designed to plant small grains for larger animal-powered farmers at uniform depths with more uniform distribution than possible by broadcasting. The maximum working width of a three-row drill set for 25 cm. spacing is 62 cm. Drag chains are used for seed covering and the rear wheels power the seed-metering mechanism and fertilizer attachment through a chain drive. The price for a three-row Cossul drill with fertilizer attachment is about $150.00 A hand-controlled fore-carriage is useful to keep the drill running straight.

Hopfen points out:

> The main purpose of drilling in rows is to place all the seed at a predetermined uniform depth and with the rows equidistant, and thus save up to 25 percent of seed as compared with broadcasting. Drilling also facilitates subsequent intercultivation and weeding with hand- or animal-drawn implements.[65]

2) Output, Power, Time and Labor Required

a) Broadcasting Methods using the plow for covering require two oxen. In Ethiopia, Bengtsson found it took an average of 23.3 hours to plow one hectare and 4 hours to broadcast the seed for a total time of 27.3 man-hours and 46.6 ox-hours.

b) Plow Tube Seeder While no actual time studies were made, the rate of work was calculated. As reported by Moczarski, the Awash Valley maize farmer plows and sows at the same time with a spacing of about 1/2 meter.[66] Fast oxen walking at an average of 1.6 kms. per hour can cover a hectare in 12.3 hours; slow oxen moving at 1 km. per hour would take about 20 hours. If the oxen worked 80 percent of the time, the average time to seed one hectare would be 20.2 hours.

c) Hand Planting Haynes gives figures in Table III. 9 on hand planting in comparison with ox-drawn planters on prepared ground. Labor requirements for ridge planting by hand versus the Super Eco ox-drawn planter, indicated a definite advantage for the animal powered units.[67]

3) Skill and Management Required

a) Hand Planting with Animal Power No particular skill is required

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[65]Hopfen, *op. cit.*, p. 77.

[66]Moczarski, *op. cit.*

[67]Haynes, A *Brief Review of Mechanization Experiments in Northern Nigeria*, p. 12.

TABLE III. 9 COMPARISON OF LABOR FOR HAND- AND OX-DRAWN PLANTERS

Crop	Method	Time Required
		Hours per hectare
Groundnuts	Hand planted	28.7 man-hours
	Machine sown	n.a.
Guinea corn	Hand planted	39.5 man-hours
	Machine sown	3.7 hours

to plant and cover the right number of seeds in a hole of the proper depth. It takes skill and management, however, to prepare the land for a variety of crops, to plant them at the proper time, to weed early food-crops as needed, and to harvest the late crops and cash-crops on time, without neglecting any aspect of good husbandry. The more mixed-cropping and larger the area, the better manager the farmer must be. As Haynes pointed out, during the first 15 years of promotion in northern Nigeria, many mixed-farmers, as they increased their area, required techniques beyond their capacity. About 1/3 of all new farmers using animal power failed after acquiring cattle and plows; some due to animal diseases but many more because of the inability of the individual farmer to change his role from head of the family farm to *manager* of the mixed farm.[68]

It also takes skill, management and foresight to plot fields for row seeding to facilitate subsequent cultivating and weeding. Rows should be as long and straight as possible; hills must be centered to permit close work and labor-saving weeding with improved animal or hand tools. If weeding is to be done with a two-row mechanical cultivator, special care must be used in hand planting single rows by using a 2 or 4-row marker. In addition Shambaugh cautions, "Using the heel-and-toe method of hand planting, the covering should be done with a backward motion of the foot rather than a side motion which may tend to move the seed to a closer or wider row spacing."[69]

b) Row Planting with Plow Tube Seeder The greatest difficulty is guiding the oxen in a straight line while maintaining a constant rate of seeding. Two persons undoubtedly can do a better job, as in Ethiopia where a boy helps his father by dropping the seed into the tube.

c) Animal-drawn Mechanical Seed Planters The farmer using a machine planter must choose the correct plate or star for the available seeds.

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[68] D.W.M. Haynes, "The Development of Agricultural Implements in Northern Nigeria", *Proceedings, Science Association of Nigeria* Vol. VI, 1963, p. 103.

[69] Shambaugh, *Bornu Complete Tillage Machine*, p. 6.

Once he has chosen a seed plate, he must select the cleanest and most uniform seed to be used with it. As varieties are improved or new crops introduced, he may try to get by with an old plate rather than purchasing the correct size plate.

In using the seed planter or drill, the farmer must constantly check to see that seed is dispensed and that soil or foreign material neither clogs the seed discharge or blocks the shoe or seed tube opener. In Senegal, this problem is partially overcome by having a boy or man lead the animal while the farmer concentrates on the seeder.

Under hot tropical conditions it is also very desirable to use a press wheel after the seed is covered, to insure that the seed is firmly embedded within a moist environment. Because of occasional downpours, seeds must be firmly covered, especially on sloping land, to prevent their being washed away. Under dry conditions different spacings may be required. Types of furrow openers are also important. Hopfen points out:

> In average soils hoe-type openers are preferred; in cloddy soil or in soil with trash, roots or other organic materials, single disk furrow openers generally function best. . . . While the normal spacing between the rows is 16 to 18 cm. for cereals, under dry conditions this spacing must be wider, namely, about 25 to 30 cm.
>
> [Furthermore] if winds are frequent in drier areas, cereals should be dropped into the bottom of rather big furrows and pressed into the soil with rollers. [For protection from the wind and to control wind and water erosion] the seed rows should be perpendicular to the prevailing direction of the wind and surface trash should also remain on top of the ridges.[70]

4) Costs Involved

A summary of man-and animal-power requirements for seeding by various methods as outlined in this section is given in Table III. 10, and indicates the amounts of inputs with different levels and degrees of mechanization. For comparison purposes only the value of one man-hour is assumed to be \$0.10 and the cost of two ox-hours \$0.20. However, since both labor and animal costs are quite different in different economies more realistic comparisons can be made in terms of actual work hours, which are also shown. Additional studies are needed which enable comparisons of similar operations in different countries.

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[70] Hopfen, *op. cit.*, p. 83.

TABLE III. 10 COSTS OF SEED PLANTING FOR DIFFERENT ANIMAL-POWERED SYSTEMS

Method	Crop	Operation	Man-hrs./ha.	Ox-hrs./ha.	Cost of hand labor dollars	Cost of animal labor dollars	Total cost/ha. dollars
Broadcasting[a] (Ethiopia)	Wheat Barley	Covering Sowing	23.3 4.0	23.3	2.73	4.66	7.39
Plow Tube Seeder[b] (Ethiopia)	Maize	Plowing Sowing	20.2 10.1(boy)	20.2	3.03	4.04	7.07
Hand Planting[c] (Nigeria)	Guinea Corn	Plowing Sowing	39.5	-	3.95	-	3.95
Hand Planting[c] (Nigeria)	Groundnuts	Hill Planting	28.7	-	2.87	-	2.87
Cossul 3-row drill[b] (Tanzania)	Small Grain	Drilling	5.0	5.0	0.50	1.00	1.50
Super Eco Ox-planter[c] (Nigeria)	Guinea Corn	Drilling	3.7	3.7	0.37	0.74	1.11

[a]Bengtsson, *op. cit.*, pp. 10 and 24.

[b]Times and costs calculated from available information.

[c]Haynes, *Ox-drawn Implements*, p. 12.

Weeding and Inter-cultivation

Irregularly-spaced and haphazardly-located plants are very difficult to cultivate and can be weeded only with a great deal of time and effort. Crops planted in rows uniformly spaced, with sufficient distance between them, can be easily and quickly weeded. When soil conditions are favorable and the seedbed has been properly prepared, labor-saving, high-capacity tools and implements can be used for inter-plant cultivation and weeding to greatly expand the farmers capacity to control plant environment on larger areas. Weeding is considered the major constraint limiting the area that can be effectively cultivated by the small annual crop farmer, especially tenants and share-croppers.

Weeding has long been recognized as an essential practice by farmers. Pankhurst quotes an early account by Salt:

> In Tigre after the plowing, the womenfolk used rude, hooked instruments to break the clods and 'most carefully' picked out all the weeds; if this weeding, however, was not sufficient, men, women and children would collect when the corn was half ripe and forming a line, would pluck out the weeds with singing and much merriment.[71]

Technical Factors and Constraints

Hand Weeding Operations

1) Tools and Practices

Hand farmers have few tools and most of these serve several purposes. Tools used for inter-cultivation usually are the same tools used for secondary tillage and perhaps primary tillage. Various types of short-handled hoes and a few long-handled hoes are owned and used by hand farmers in Equatorial Africa. They exist in different weights, shapes and sizes but usually are lighter and wider than hoes designed for digging and primary tillage. Weeding sickles are not used as much in Equatorial Africa as in parts of Asia and the Far East. In a few areas, traditional chopping hoes are being replaced by lighter weeding tools where row cropping has been introduced.

a) Ethiopia Bengtsson made a study of cultivation practices in the hand- and animal-powered highlands of central Ethiopia. While hoes are used in weeding, hand picking is still the most common method. He points out, however, "hand picking of serious tall-growing weeds is seldom carried

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[71] Richard Pankhurst, *Economic History of Ethiopia, 1800-1935* (Addis Ababa: Haile Selassie I University Press, 1968), p. 187.

out between plowings."[72] Furthermore, "in spite of the plentiful weed-plants at planting time, there is no special weeding carried out before the seed is broadcast."[73]

Soil burning is practiced also in certain areas in order to prepare fallow sod land for cultivation. Bengtsson says burning "is almost the only way of getting rid of all grasses and their roots. The loosened sod is collected and piled in heaps by hand and set afire with burning dry cow dung."[74] (Figure 2.5.)

In the lowlands of southwest Ethiopia, (Pokwo/Agnalc), the narrow-bladed *challa* (hoe) is used for weeding. The fields are weeded with the same hoe twice in the spring and once in the fall in a normal season. The *challa* has a metal blade about 6 cm. wide by 8 cm. long which extends into a wrap-around socket 8 cm. long, into which a straight handle is usually inserted. The handle may be 90 cm. or longer. Sometimes a right-angle handle is used in place of a straight handle. (Figure 2.11.)

The Awash Valley plantations (Middle Awash Settlement and Tendaho) and farmers have adopted a long-handled hoe with a rectangular blade similar to those used in Kenya and Tanzania except the blade is a little longer. (Figure 3.23.)

b) Kenya and Tanzania The same *jembe* (hoe) used for primary and secondary tillage is used for weeding and inter-cultivation. Sometimes narrower blades are used to work closely around plants. Blades are being made in Nairobi by at least two firms and are sold through hardware stores and farmers cooperatives. The blade is similar in shape to the hoe in Figure 3.23.

c) Ghana The hoe called a *kpakpla* has a medium length handle 60 to 70 cm. long and either a squarish or round-shouldered blade 12 cm. wide and 15 cm. high set at an angle of about 60° with the handle. The blade can have a tang for insertion into the enlarged end of a wooden handle, or it may have a tubular socket into which the handle is fitted. Many variations exist, depending upon the preference of the local blacksmith and the accepted form in the community. (Figure 3.1 and 3.2.)

In some parts of Ghana, particularly the southern forest belt, farmers also use a short-handled cutlass for weeding. It is shoved into the ground at the base of the weed to cut off the root. Small weeds are flipped out

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[72] Bengtsson, *op. cit.*, p. 5.

[73] *Ibid.*, p. 21.

[74] *Ibid.*, p. 11.

Figure 3.23 Long handle heavy hoe used for weeding in eastern Ethiopia
The long steel blade is imported but well suited to this area where weeds are especially difficult to control on flood irrigated plains. In contrast to most traditionally used short-handled tools the people in this area prefer long handles. (AFR-20)

with the tip of the blade. Hand pulling weeds around plants also is common.

d) Nigeria The Nigerians use a short-handled weeding hoe, called a *garma*, made primarily by village blacksmiths. The metal blade is hammered out of old auto metals. The triangular-shaped blade, about 15 cm. wide at the bottom gradually tapers to a pointed tang at the top which is driven into a hole in the handle head. The 60 cm. long handle gracefully curves to form a hand grip and the blade curves inward so the tip points back toward the operator. When the angle of the blade with the handle is correct, it makes a very well-balanced tool. For weeding around random-spaced plants and on ridges, Nigerian farmers say it is much better than a long-handled hoe. (Figure 3.24.)

e) Senegal and Ivory Coast Similar short-handled hoes, called *dabus* in Senegal, were observed in use in other parts of West Africa. The farmer works in a bent position and rapidly hoes the weeds out with one hand and shakes them with the other to remove the dirt from the roots.

The women in Senegal use a special long-handled hoe called an *iler* or *hilaire* for preparing rice paddies. They normally work together in groups; sometimes an entire community will participate, led by one who sings and dances to encourage the others. (Figure 3.25.) The *iler* has a flexible

Figure 3.24 Short-handled *garma* weeding hoe This common hand tool is a popular tillage implement in northern Nigeria. For labor accustomed to stooping it is a very efficient weeding tool and especially well-liked for ridge farming. The blade is made by the local blacksmiths and the handle is generally very carefully selected and fitted by the farmer. (AFR-332)

Figure 3.25 Long-handled hoes in West Africa Women hoeing rice paddy with long hoes called *hilaire* in preparation for planting rice seedlings in the Casamance Region, Senegal. The handle made from a sapling has a natural right angle bend about 40 cm. from the blade end. (AFR-522)

handle 190 to 220 cm. long to which is attached a small socket-type hoe blade from 6 to 8 cm. wide. The blade is positioned on a shaft at a right angle to the main handle at the root end of a sapling.

2) Power Required

All weeding hoes in equatorial Africa can be used by men, women or older children. Every farm has at least one hoe and often two or more, generally one for each adult member. Children are expected to pull weeds by hand. The biggest limitation in power for the hand farmer is the number of people he can muster for weeding. The tendency is to let the weeds get too large before attempting to control them.

In Ethiopia as many as 16 to 38 weed-plants per crop-plants were reported by Bengtsson. He says that while farmers "suggest frequent weeding as a remedy", they do not practice it. Their "complaints are always the same, *e.g.* lack of labor and lack of cash."[75]

Sommerauer compared the weeding capacity of various hand tools. He says, "as against the weeding sickle's very low capacity of 3 $m.^2$ per hour, the digging hoe's capacity is 70 to 150 $m.^2$, and that of the pulling hoe 200 to 400 $m.^2$" He points out, however, that "if modern hoeing implements are to be used efficiently, crops must be planted in rows." For example, pulling hoes can not be used in mixed crops of spinach and onions which have been broadcast and stand close together.[76]

3) Time Required

a) <u>In Ethiopia</u> As a rule, cereal crops of wheat, barley and *teff* are weeded once; maize and sorghum are weeded twice after a plowing carried out as the first weeding and thinning operation.[77] No time studies of work rates were made.

b) <u>In Nigeria</u> Shambaugh states:

> The native Nigerian farmer has found it only expedient to farm as much as he can properly weed. With the equipment he is presently using, a single hand-farmer is only capable of taking good care of approximately three acres. Depending on the season, general field weeding will rarely need to be done before planting of millet, probably before guinea corn, but generally always before planting of groundnuts and cotton which are planted at a much later date.[78]

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[75] *Ibid.*, p. 45.

[76] W. Sommerauer, *Small Agricultural Implements: Report to the Government of Afghanistan*, Report No. 23, (Rome: Food and Agricultural Organization of the United Nations, May, 1952), p. 14.

[77] Bengtsson, *op. cit.*, pp. 46-47.

[78] Shambaugh, *Mechanized Assistance to Hand-Farming*, p. 2.

Shambaugh gives a detailed summary of hand operations performed by one man with a hoe as his only tool in farming 4 hectares comprising 1.2 hectares each of millet and guinea corn and 0.8 hectares each of groundnuts and cotton. The farmer, in caring for this area (large by present standards), was assisted by a 45-horsepower tractor and a special tillage machine at crucial times for certain operations such as primary tillage; once-over field cultivating, fertilizing and row-marking in preparation for hand planting; row-crop cultivation of all crops twice (except cotton only once), and putting a side-dressing of fertilizer on millet and guinea corn. The total hours of machine work for all these operations was only 14.3 hours or about 3.7 hours per hectare.[79] The special tillage machine developed by Shambaugh for assisting hand and animal farmers is called the Bornu Complete Tillage Machine and is described below under engine power.[80]

Shambaugh says,

> The farmer was busy for most of the crop season (April to August, 1968) and was a good worker. . . . With the assistance of the Bornu Complete Tillage Machine, the fields were clean and the crops looked very good at harvest time. [He further said] if the farmer had been farming any more than 4 hectares under this plan, all by himself, he would have been short of time for thinning and weeding and would have had to use additional machine work for weeding.[81]

Table III. 11 summarizes the hand-weeding operations of one hired worker using a hoe in northeastern Nigeria. These hand-rate-of-work capacities, however, are higher than could be obtained with broadcast or randomly planted crops because the laborer is working in straight rows of spaced plants, which facilitates weeding.

In another weeding trial at Maiduguri in August, 1964, Shambaugh reported that hired hand laborers were able to weed row crops (doing no thinning) at a rate of 0.023 hectares per man-hour or 43.2 hours per hectare. These rates are probably much faster than average, since the men knew they were being timed. Had there been more weeds and grass present, the soil would have had to have been broken up into smaller pieces, requiring additional time and labor.[82]

c) <u>In Ghana</u> Sokah made a study of tomato production in the southern Accra plains. Using a medium-handle *kpakpla* (hoe), it took four men 37

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[79] *Ibid.*, p. 8.

[80] Shambaugh, *Bornu Complete Tillage Machine*, p. 21.

[81] Shambaugh, *Mechanized Assistance to Hand Farming*, p. 8.

[82] Shambaugh, *Comparison of Hand and Machine Cultivation Costs*, p. 5.

TABLE III. 11 SUMMARY OF HIRED HAND-LABOR IN WEEDING FOUR HECTARES OF ROW CROPS: NORTHEASTERN NIGERIA 1968[a]

Date	Area	Operation	Crop	Total Time	Average Rate	Average Cost[b]
	hectares			hours	hrs./ha.	dollars/ha.
May 1-9	4.0	Weeding before planting	-	63.3	15.6	1.71
June 17-25 June 27 - July 3	1.2	Thinning and close weeding	Millet	106.5	87.7	9.64
July 4-11	1.2	Close weeding	Guinea Corn	57.0	47.0	5.17
July 12-20	0.8	Close weeding	Groundnuts	65.3	80.8	7.90
July 26-31	0.8	Close weeding	Cotton	40.5	50.2	5.51
Aug. 1-10	1.2	Weeding, second time	Guinea Corn	72.5	59.8	6.62
Aug. 12-31	0.8	Weeding, second time	Groundnuts	147.0	181.5	19.93

[a]Shambaugh, *Mechanized Assistance to Hand Farming*, p. 7.

[b]Based on wage rate of $0.11 per hour actually paid to hired labor in this area in 1968.

Note: From June 26 to July 30, the farmer was assisted by a tractor tillage machine in weeding at critical times on each of the four crops by inter-row cultivation. While the total time spent in machine tillage was only 6.7 hours, it met a critical need of rapidly weeding the large inter-row spaces, allowing the farmer to concentrate on the in-row thinning and weeding during which time he was fully employed.

hours to weed one hectare, or 148 man-hours per hectare. Tomatoes required three hand weedings for control.[83]

4) Skill and Management Required

Based on five years' experiments in comparing different levels of power for crop production, Shambaugh points out, "When the farmer needs to hire additional labor for weeding, he often finds that it is not available because everyone is busy weeding his own crops at the same time."[84] "The hand- and animal-powered farmers need to be assisted by tractor-powered machinery, but at the same time their labor must be used to the fullest extent of their ability."[85]

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[83]A.K. Sokah, Mechanical Superintendent, Greater Accra Region, Ghana Ministry of Agriculture, Amasaman, Ghana, Personal Communication, November, 1968.

[84]Shambaugh, *Comparison of Hand and Machine Cultivation Costs*, p. 3.

[85]Shambaugh, *Bornu Complete Tillage Machine*, p. 1.

Since the normal hand planting operation is to plant a pinch of seed, thinning becomes a necessary practice as soon as the plants become well established. Close weeding also is done by hand at this time.[86]

The Nigerian farmer plants guinea corn and groundnuts after millet. If fields for these later crops are not cultivated before planting to kill all weeds, Shambaugh notes, "the farmer had to put in considerably more hours hand weeding groundnuts."[87]

Even if farmers admit that they have a serious weed situation, they fail to realize the true significance of the weed competition. High yield increases often can be obtained by slightly intensified weeding which more than pays the additional cost of hired weeding. This has been shown in weeding experiments by CADU in Ethiopia.

In Ethiopia Bengtsson reports:

> The present weeding efficiency means a weed plant reduction of about 50 percent, but this effect is only temporary, unfortunately. The environment will, however, favor both regrowth of once eradicated weeds and development of seedlings, left growing at the date of weeding. Therefore, the weeding procedure should be repeated several times, which is quite possible since the time requirements do not necessarily mean a significant increase of working hours; the more frequent the weeding is carried out, the less weed plants. More intensified weeding may in the initial stage also be combined with row planting, preferably. This will apply to crops such as maize, sorghum and beans which easily could be hand planted.
>
> Broadcasting may be used but modified in the way that seeds should be dropped only in every third or fourth furrow followed by seed covering, thus giving a proper row spacing. This will facilitate the mere weeding which easily could be repeated without any risk of destroying the crop by broken plants. Furthermore, the row planting will lead the way to introduction of a simple long-handled hoe. Although these are major changes compared to the traditional method, they mean a very definite yield increase by which it would be relatively easy to adopt the new practice. It is a cheap method, it does not require any special investment, and its effect is drastic and easily demonstrated. The additional labor gives a good profit and particularly when combined with row planting when also seed may be saved. . .[88]

Hopfen points out that:

> Crops planted in rows with regular, sufficiently wide spaces and a soil that is not too cloddy, can be cultivated

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[86] Shambaugh, *Mechanized Assistance to Hand Farming*, p. 6.

[87] *Ibid.*, p. 9.

[88] Bengtsson, *op. cit.*, p. 61.

> with chopping hoes or weeding knives with great expenditure of labor and time . . . a farmer and his family are able to cultivate only very small plots properly in this way.[89]

5) Costs Involved

Adjusting Shambaugh's quoted rate for hand labor at the Farm Center in Maiduguri to present labor costs of $0.90 per 8-hour day or $0.11 per hour, hand weeding costs $4.89 per hectare.[90]

In a comparison of hand operations and mechanical assistance to hand farming, Shambaugh recorded the actual times given in Table III. 11. For thinning and close weeding, the costs per hour ran considerably higher, depending on the crops and nature of weeds, ranging from $5.17 to $9.64 per hectare. The cost of the second weeding varied even more, depending on the crop and previous tillage practice. Low costs were associated with weeding guinea corn.[91]

Animal Weeding Operations

1) Tools and Practice

Larger fields can be cultivated with modern animal-drawn implements rapidly and efficiently provided the crops are properly spaced and planted in straight rows with adequate space between them for the movement of cultivation equipment. Broadcast or irregularly spaced crops can only be cultivated laboriously with small hand tools at great expense of time and effort. Worst of all the weeding is only temporary because of the incomplete and unsatisfactory nature of the work.

Normally, crops are cultivated only in one direction since plants are randomly spaced in the rows. Sometimes if weed problems are serious, or if hand labor is scarce or too expensive, crops can be check-rowed and lined up perpendicularly to the rows to permit cross cultivation. This practice was observed in Senegal and is recommended by the Bambey Centre for Agronomic Research to animal-power farmers. (Figure 3.26.)

The main purpose of inter-cultivation is to eliminate weed growth as a limiting factor in crop production. Crop rotations using row crops after small grains may be necessary to permit intensive weeding. One of the principal reasons for advocating row-cropping is to facilitate subsequent hoeing and weeding. Secondary objectives of inter-cultivation may be to

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[89] Hopfen, *op. cit.*, p. 86.

[90] Shambaugh, *Bornu Complete Tillage Machine*, p. 9.

[91] Shambaugh, *Mechanized Assistance to Hand Farming*, p. 7.

Figure 3.26 Weeding by cross-cultivating rice A steerable ox-drawn cultivator developed at the Bambey Centre for Agronomic Research in Senegal and mounted on a French-designed tool-bar. Note the upright standards by each wheel onto which a platform or box can be mounted for hauling produce or supplies to market. In this French system the implement tongue is fastened to the yoke attached to the animals horns by straps. Two operators are always required; one to drive the oxen and one to steer and watch the implement. (AFR-547)

loosen and aerate the soil, ridge up plants, or side-dress with fertilizer.

Many of the implements used in secondary tillage for seedbed preparation can be used for weeding and inter-cultivation. In some countries farmers may have only one or two implements that are used for all purposes. Tools made specifically for weeding are superior; several improved types of cultivators and weeders have been introduced in Equatorial Africa. Until sufficient demand can be built to warrant local manufacture, selected machines should be imported to acquaint agricultural services and farmers with their capabilities. So far, more progress has been made in French-speaking western and central African countries to introduce better animal-drawn equipment. (Table III. 8.)

a) Animal-drawn Hoes A light cultivator or hoe, pulled by a horse or a donkey, is a very common sight in Senegal. More are found in Mali, some 82,000 according to the 1965 census reported in Table III. 8. While single-purpose hoes are less expensive, there is a growing trend toward multiple-purpose tools and toolbars as described on pages 2-181 - 2-197.

The most widely sold hoes in Equatorial Africa are the single-row hoes, Occidentale and the Sine 7, developed by French manufacturers and made by SISCOMA in Senegal. They are simple multi-purpose hoes developed for inter-cultivation of row crops grown by small farmers in tropical and semi-arid climates. Each can be drawn by an ox, donkey or horse and consists of a front-wheeled two-handled frame to which can be attached, at adjustable spacings, three cultivator tines, two weeding shares, one large duck-foot

sweep and two tines, or one ridging body. The implement with attachments weighs about 15 kg.

The Lever-expansion cultivator, imported into eastern and western Africa from India, England and Israel, is a five-point one-row cultivator based on McCormick design.[92] It can be easily and instantly adjusted by lever for different widths of row crops from 30 to 63 cm. (Figure 3.27.) Uses include seedbed preparation as well as inter-row weeding and cultivation. The shovels are reversible for double wear, and right and left moldboards and double-face shovels are available for the rear gangs for throwing soil around plant roots or making small irrigation furrows. It weighs about 35 kg. and sells for $21.00 in Tanzania.

Many of these units were imported into Ghana in the early sixties, but they have not been widely distributed. Some remain boxed in the Ministry of Agriculture Workshops in southern Ghana waiting transfer to the northern and upper regions where animal power is used. (Figure 3.28.)

For single and multiple rows the expandable horse hoe is a common implement world-wide for deep row-crop inter-cultivation and weeding. Many width adjustments and patterns of tines are used. The implement is steered with two handles at the rear, and an adjustable front wheel controls the depth.

A more advanced version known as the steerage horse hoe is a multi-row implement with a two-wheeled fore-carriage and a tine frame. Steered independently of the draft animal, it allows precision cultivation, important in most crops grown in rows.

Multiple-row tools are being introduced with ox-drawn toolbars and toolframes, but expensive single-purpose tools such as the steerage horse hoe are not likely to become popular in Africa.

b) Rigid-Tine Animal Cultivators For inter-row cultivation and final seedbed preparation, the cultivator normally has wide blades or shovels designed for shallow work. Flexible and semi-rigid tines are more expensive and are draft-saving only at fairly high speeds. They have no advantage with slow animals over rigid tines fixed to a solid frame. Hopfen states:

> The cultivator is a very versatile implement derived from the symmetric *ard*. . . It is used for clod breaking, stubble mulching, seedbed preparation and seed covering in arid zones either on dry or irrigated land, for weeding and inter-row crop hoeing. In semi-arid regions where draft animals are sufficiently

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[92] Cossul and Company Private Ltd., 123/367 Industrial Area, Kanpur, India; Charles Weir, Ltd., Townpark Works, Strathaven, Lanarkshire, Scotland; and Technohac Agricultural Machinery and Implements, Ltd., Petah-Tikva, Israel.

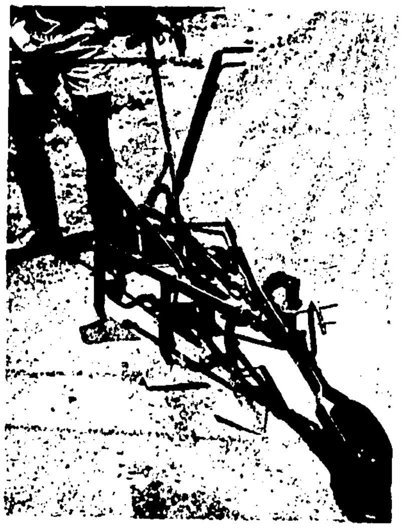

Figure 3.27 Cossul (Indian) lever-expansion cultivator Once commonly used in small farms in western countries, this tool has been introduced into Asian agriculture and is now entering African countries. While it is basically a cultivator, a variety of shovels and attachments can be added. It can be pulled by a single animal but it should be well trained for single operator control. The width is adjustable from 25 to 63 cm. but this mechanism makes it much more complicated than the 3-tooth single-handle cultivator shown in Figure 3.29. (AFR-510)

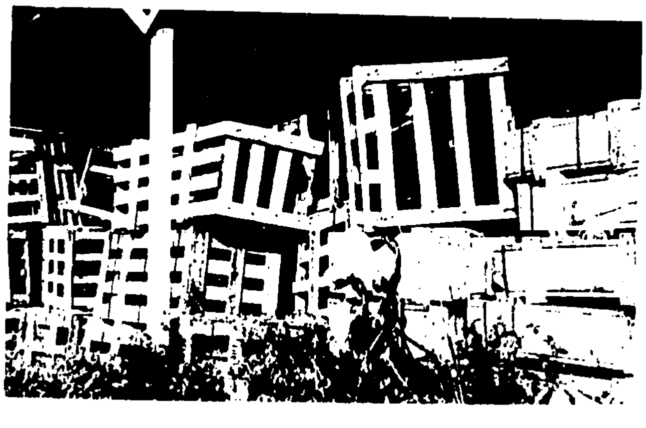

Figure 3.28 Boxed improved hand- and animal-powered tools in western Africa These tools, primarily cultivators, maize shellers and pedal rice threshers, were imported 3 to 6 years ago for demonstration and trial by small farmers. (AFR-366)

strong, the moldboard plow is being replaced more and more by the cultivator for primary tillage. This implement, normally drawn by a pair of animals, consists of a cross-bar and usually five curved staggered tines.[93]

The German Rhino cultivator was tested at Samaru and "good crops of guinea corn and groundnuts were grown without any hand weeding."[94] The cultivators, which were on the Northern Region Standardization List from 1957, are still used at Samaru, although they have been replaced to some extent by a newly designed weeder which is more suitable for tied ridges. The working rate is 6 to 10 hours per hectare, but the cultivators do not work well in wet soil. Price in 1964 was about $30.00.

Braun tested the Ulysse Fabre hoe in Niger by harnessing a donkey with a longer rope (4.5 m. instead of 3.5 m.) around the breast. He said, "lateral movement of implement can be easily made to allow hoeing between plants in rows and it reduces hand labor to a minimum.[95]

Braun also made an experiment using a single ox as a draft animal to hoe millet with a tool carrier *Arara*. He used a single neck yoke, two chains 2.5 meters long, a single bar and the *Arara* toolbar equipped with 50 cm. sweeps. Results were excellent and the single neck yokes of Swiss origin worked very well.[96]

The Indian-type single-handle cultivator is a three-tine cultivator patterned after the traditional breaking plow with a long rigid beam and set of shovels attached. The width can be adjusted easily by bolting the tines to different holes in the frame. Depth is adjusted by changing the height of the beam in relation to the frame with other holes. Models from various firms are available with sweeps of different sizes. One of the simplest, a RN cultivator made by Cossul, weighs 16 kg. and can be converted into a moldboard plow, with or without a seeding attachment. (Figure 3.29.)

The Vikas Jr. cultivator has a more intricate frame and several more attachments. In addition to the moldboard plow and weeding attachment, a ridger plow and fertilizer distributor are available. The cultivator weighing 16 kgs. is similar to Figure 3.29.

c) Animal-Drawn Blade Harrows A typical Indian implement for

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[93]Hopfen, *op. cit.*, pp. 63 and 66.

[94]Haynes, *A Brief Review of Mechanization Experiments in Northern Nigeria*, p. 14.

[95]H.J. Braun, *Niger: Development of Agricultural Use of Animal-Drawn Plows in Niger: Report to the Government* (Rome: Food and Agricultural Organization of the United Nations, 1967), p. 4.

[96]*Ibid.*, p. 2.

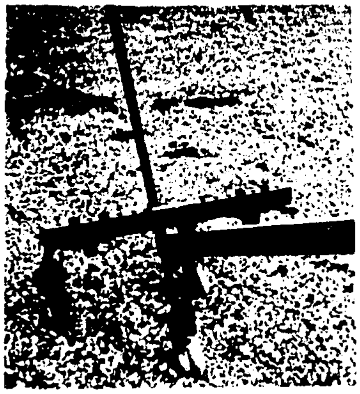

Figure 3.29 Cossul RN or Vikas Jr. (Indian) simplified animal cultivator Distinguished by a single handle, these inexpensive three-tooth cultivators are designed around the conventional breaking *and* concept. A long rigid tongue utilizes the most popular type of hitch for animal-power using the ox team. The row coverage spacing can be varied by rebolting the teeth in selected holes of the cross frame. These units can be produced locally by a trained blacksmith. (Photo courtesy of B. Karlsson, CADU/SIDA, Asella, Ethiopia, April 1969) (AFR-460)

destroying weeds, described by Hopfen, may have a place in tropical climates, particularly in arid and semi-arid climatic zones. It is good for secondary tillage and inter-cultivation, provided the ground is even and free of stones and big roots. It consists of a sharp steel blade, with a working width of about 40 to 60 cm., carried on two supports fixed to a wooden beam or iron frame with a central pole for two-yoked animals. The slightly declined blade drawn through the upper soil level produces a good mulch and destroys weeds.[97]

d) Flexible Animal Harrows These units are used for weeding and very light tillage during early stages of crop growth, seed-covering and spreading manure on pastures. Constructed of light metal rods and bars, these units could be easily fabricated by small workshops and metal industries in developing countries. While not used to any extent in Equatorial Africa by the small farmer, flexible harrows have large potential. This harrow is sometimes constructed so that one side has longer teeth to provide two harrows in one. (Figure 3.30.)

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[97]Hopfen, *op. cit.*, p. 63.

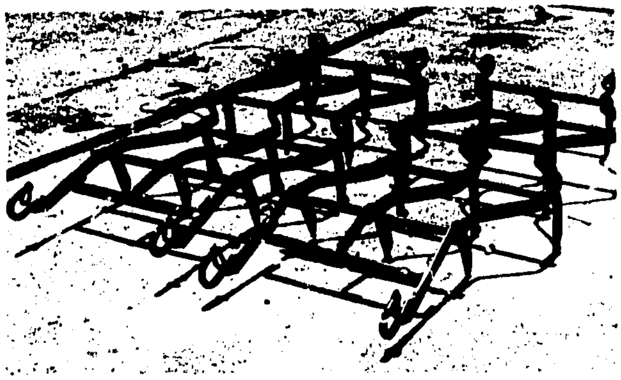

Figure 3.30 Agra (Israeli) simple all-steel semi-flexible harrow In areas where the breaking plow is the only implement owned by most farmers, there is a need for some type of secondary tillage implement, particularly for seed coverage. This type could be made in a developing country from modular steel pieces or assembled from standard imported components. Many styles and configurations are available. (AFR-537)

2) Output, Power, Time and Labor Required

a) Single-Row Hoes Power required is a donkey, small horse or ox. Output of the lever-expansion five-shovel cultivator ranges from 1.2 to 1.6 hectares per 8-hour day while the German Rhino cultivator's work rate varies from 0.8 to 1.2 hectares per 8-hour day. Man-hours run from 5 to 10 hours per hectare. One man can guide the cultivator and a well-disciplined animal at the same time. In most cases observed a boy or woman leads or rides the animal.

b) Multi-Purpose Two-Row Toolbar Cultivators No research data were available on the capacity. In Senegal, farmers were observed using toolbars for two-row cultivation. In all cases, two men operated the implement, one man driving the oxen and the other man steering the toolbar cultivator. (Figure 3.26.)

Power required two oxen and output is estimated at 1.6 to 2.4 hectares per 8-hour day. Man-hours with two men are 6 to 10 hours per hectare. Two men are needed with normal whip and voice control, but this could be reduced to one man and 3 to 5 hours per hectare by using the Indian system with nose rings and lines. (Figure 3.31.)

c) Single-Row Indian-type Cultivators (Manufactured by Cossul and Co. Pvt. Ltd.). Power required is two oxen, although cultivators could be

Figure 3.31 Improved nose ring and line system (European and Indian) for ox control Along with improved animal tools and implements there is a need for better methods of hitching and controlling draft animals. For good work and most efficient use of implements animals must be taught to walk in straight lines and be quickly and easily corrected when necessary. Using the yoke system without lines, or with lines only to the head or horns, adequate control cannot be obtained except by using at least two operators and leading the animals. With individual nose rings and lines, one man can control both the implement and the animals, the accuracy depending on degree of training of man and animals. (Photo courtesy of B. Karlsson, CADU/SIDA, Asella, Ethiopia, April, 1969) (AFR-468)

modified for single animal draft by replacing the rigid pole with two shafts, or possibly a singletree and two ropes. Output, according to the manufacturer, is 1.2 to 1.6 hectares per day for either the RN three-tine cultivator or the Vikas Jr. three-tine cultivator. With a single operator the time required is 5 to 6.6 man-hours per hectare. Unlike straddle-row cultivators, these single-handled implements can be operated between the rows by one man.

3) Skill and Management Required

Weeding is the animal-powered farmers most severe limitation. Although he has greatly increased his capacity to prepare land for planting, he is often unable to effectively weed it with the traditional techniques and tools at his disposal. Two prerequisites must be met if the animal-powered farmer is to be able to keep his crops clean and free from damaging weed competition.

a) Pre-Planting Weed Eradication First, *he must do a better job of seedbed preparation and preplanting weed control.* In Ethiopia, this

means developing a more effective system of primary tillage either by improving the indigenous plow or replacing it with a more effective tilla[ge] implement. Even with three to four plowings, as Bengtsson found,

> The soil surface is only scratched by the plow and there is little weed control. [He also noted] no hand-weeding takes place, neither between different plowings nor before planting . . . it is not surprising to note 220 weed plants, as an average per square meter in fields prepared for planting. [He said] farmers seem to be aware of the weed situation and emphasize that weeds are of particular importance in their crop production, but they do nothing about it.[98]

In northern Nigeria and Ghana, the ground gets very hard as it dries out. Shambaugh says the primary tillage with a chisel-plow or heavy-duty field cultivator should be done "as soon as possible after harvest before the ground becomes excessively hard. The ground is left with as large clods as possible in order to absorb the maximum amount of moisture from the first rains, as well as being a very poor seedbed for encouraging the growth of early weeds."[99] For field weeding, he recommends the use of wide-sweep shovels (such as 40 cm. wheatland sweeps) overlapped 5 cm. to [c]off all weeds. It is advisable to kill all of the weeds before planting when there are no plants that must be saved. No weeds should be allowed t[o] get over 5 to 8 cm. tall.[100]

Most animal-powered farmers make the mistake of allowing weeds to become too large before attempting to eradicate them, or they simply plant in weedy fields hoping to be able to get rid of the weeds by early hoeing or hand weeding. If the farmer has done a good job of primary tillage, few weeds will impede plant growth in normal weather. Depending on the season, general field weeding will rarely need to be done.

b) Row Planting for Weed Control Secondly, the ox-plow farmer plant in rows properly spaced and aligned so that he can employ more produ[c]tive, time-saving, less expensive and effective means of weed control. Wh[ile] chemical herbicides can control most weeds, they are much too expensive no[w] for the emerging farmer in Equatorial Africa in his present stage of econo[mic] and agricultural development.[101] In the meantime with more diligent and frequent weeding by hand, hoe or animal cultivation, all facilitated by spaced-row-planting, the farmer can greatly improve his economic returns.

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[98] Bengtsson, *op. cit.*, pp. 58-60.

[99] Shambaugh, *Mechanized Assistance to Hand Farming*, pp. 4-5.

[100] *Ibid.*, p. 5.

[101] Bengtsson, *op. cit.*, p. 50.

High yield increases may be obtained by slightly intensified weeding at small added cost.

Bengtsson states, "emphasis should be put on simple innovations, one of which is the row planting combined with regular weeding. The row planting will facilitate the weeding and the regular weeding will raise the yields."[102] While hand weeding and hoe weeding are aided greatly by row planting, a much greater increase in output can be achieved with improved animal-powered weeding implements.

Using a single-animal one-row hoe, a farmer can clean out most weeds in 5 to 10 hours per hectare. And by cultivating two or three times per month instead of hand weeding once, he can achieve greater weed control in one-sixth of the time even allowing for three cultivations, each at ten hours per hectare. Some hand weeding may still be needed, but it would be less urgent and much easier. If planting is done by hand and the farmer later uses some form of multiple row, animal-or engine-powered cultivation, the two rows must be exactly parallel. Shambaugh says, "with two evenly spaced parallel rows, two rows at a time may be cultivated at any time after the emergence of the plants, even before thinning if desirable . . . an extra cultivation costs very little and a much better job can be done when the weeds are small."[103]

Harvesting and Threshing

Harvest operations comprise cutting of stalks; separation of heads, pods, or ears; digging of roots, tubers and nuts; and collecting, gathering and handling of crops. Plants growing above ground such as small grains, forages and grasses, are usually cut off with some type of sharp knife or sickle; those growing under the ground, like groundnuts, yams and cassava are dug up with forks, hooks, or spades or lifted with special digging tools or implements.

For hand- and animal-powered farmers, threshing is usually a second operation performed at or near the farmstead. Ears of maize, however, usually are husked in the field before being transported to the storage area. More advanced engine-powered machines cut and thresh a husk simultaneously in the field. Gathering and handling of harvested crops with hand and animal power is accomplished with various tined tools, baskets and containers, sleds, carts and wagons. Engine-powered equipment includes self-unloading wagons, trailers, elevators and loading devices.

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[102] *Ibid.*

[103] Shambaugh, *Mechanized Assistance to Hand Farming*, p. 6.

Hand Harvesting Operations

1) Tools and Practices

Most hand tools are made by the local artisan or by the farmer himself. Processing equipment and techniques are generally very functional and unrefined. A few simple improved hand-operated machines are available in Africa, and some units are being manufactured in or near the capital cities: Nairobi, Kenya; Dar-es-Salaam, Tanzania; Accra, Ghana; Lagos, Nigeria; Abidjan, Ivory Coast; and Dakar, Senegal. A new metal tool factory, Ethiopia Private Tool Company, Ltd., is being established in Addis Ababa, Ethiopia. Special efforts are being made to encourage local enterpreneurs to start small manufacturing industries in most other countries. The Industrial Development Center (IDC), a joint USAID/GON project to assist small industry in northern Nigeria, is an example.[104]

a) The Sickle Of all harvesting tools used in the world today, the sickle is the most universal and ancient of harvesting tools. Huffnagel describes two Ethiopian types:

> . . . the common sickle for grain and the *Gurage* sickle used mainly for cutting grass. The grain sickle is more curved with a handle 10 to 12 cms. long and total length of blade of 35 cms. The handle and blade of the grass sickle is the same length but the blade is wider, 2 1/2 compared to 2 cms. for the grain sickle . . . The Ethiopian sickle has a serrated edge filed on the blade to increase its efficiency.[105]

Hopfen says,

> The sickle is still widely used all over the world to reap cereals, particularly paddy rice which has soft but tough straw and is easily shattered. Serrated sickles are more common in Africa south of the Sahara, in Arabia, in southern and central Iraq, in southern Iran and in Pakistan and India. Sickles with smooth edges made of good quality steel are generally used in the northern parts of the Mediterranean, in parts of Turkey and the United Arab Republic, in northern Iran, Iraq, and Afghanistan.[106]

The sickle is a one-handed tool permitting the other hand to be used to grasp and gather the cut stalks and place them in piles or in a swath. (Figure 3.32.) Some sickle blades are half-moon, others are made in a

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[104] Industrial Development Centre, *Technical and Management Assistance for Small Scale Industries*, (Zaria, Nigeria: Industrial Development Centre, n.d.).

[105] H.P. Huffnagel, *Agriculture in Ethiopia* (Rome: Food and Agricultural Organization of the United Nations, 1961), p. 160.

[106] Hopfen, *op. cit.*, p. 98.

Figure 3.32 Harvesting flax with the hand sickle in Ethiopian highlands
The hand-powered farmer's most important harvesting tool is the ancient sickle. Changed little over centuries of use it is still commonly used in developing countries wherever small grains are grown. It is favored because it is very inexpensive and can harvest rice which has a slippery stalk and is easily shattered. Most sickles are made by local blacksmiths from available metal. (AFR-346)

quarter-circle and a few shaped like a stork's bill. Generally, the cutting edge is perpendicular to the handle axis.

b) Scythe This tool used with two hands originally was designed for cutting grass in place of the slower and tiresome sickle. When equipped with a suitable collecting device, called a cradle, the scythe can be used to cut small grains. The modern scythe has a blade between 70 and 110 cm. long for grass and cereal cutting and a shorter 40 to 50 cm. blade for light brush cutting. Hopfen says, "A good length for multi-purpose blades is 75 to 80 cm. Longer blades require a skilled operator and even stoneless land."[107] Narrow blades are generally preferable because they are easier to handle and because they maintain their straight edge. The edge of wide blades tends to become corrugated when hammered. The blade width at the heel should not exceed 10.5 cm. for grass and wheat but should be wider for crops with thicker stalks.

Ground blades require sharpening on a grindstone and are most common in Europe today. Hammered blades are sharpened with a hammer and small anvil, and are preferred in hot climates because they are less liable to breakage and less fatiguing to use. Both types of blades may be sharpened

[107]*Ibid.*, p. 102.

in the field by whetting with a suitable sharpening stone. Hopfen says, "after about 120 cutting swings, a blade needs whetting and this gives the operator a short rest . . . When whetting no longer provides a razor-sharp edge after roughly 5 to 10 hours of work the mild steel blades should be hammered."[108]

In reaping with the cradle, actual mowing is done in semi-circular sweeps from the operator's right side to left. Hopfen points out:

> Since the transport of the cut material, not the cutting itself (if the blade is well-sharpened) is the tiring part of the operation, the worker should stand with his right foot slightly forward, so that his body faces slightly to the left of his straight advancing position. He thus achieves the best position, towards the end of each cutting sweep when it becomes harder to accomplish.[109]

Gabathuler suggests the scythe as a substitute for the sickle. He says, "The scythe is a cheap and very efficient tool and any farmer can use it without prolonged instruction . . . During the demonstrations, the scythe was accepted quite enthusiastically."[110]

c) Scythette This one-handed tool for grain reaping was not observed in use in Equatorial Africa. The cutting edge of the slightly curved blade is on the outside edge of the long crank handle and is used like a machete to cut downward on a slant.

d) Machete This heavy knife is used widely in Equatorial Africa for harvesting large, thick-stalked plants like sugar cane, sisal, maize and sorghum and for general clearing and brush cutting. It is used also in some areas for weeding, digging holes, sharpening poles and dressing lumber. Common blades range from 4 to 6 cm. wide and 40 to 60 cm. long, and appear in a wide variety of shapes.

A very important and widely used tool, the machete is produced by manufacturing plants in Africa: in Accra, Ghana; Port Harcourt and Abeokuta, Nigeria; and with at least three more being planned in Abidjan, Ivory Coast; Zaria, Nigeria; and Addis Ababa, Ethiopia. The R. Martindale and Company, Ltd. which makes the Crocodile brand in Nigeria and distributes them in western and eastern Africa, makes 27 standard patterns of blades, ranging from 28 to 56 cm. long and weighing from 396.9 to 935.6 g.[111] (Figure 3.33.)

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[108]*Ibid.*, pp. 106 and 113.

[109]*Ibid.*, p. 112.

[110]K. Gabathuler, *Small Agricultural Implements: A Report to the Government of Ethiopia*, Report 194 (Rome: Food and Agricultural Organization of the United Nations, 1953), p. 9.

[111]*Crocodile Machetes for West Africa and East Africa*, Catalogue No. 105 (Birmingham, England: Ralph Martindale and Company, Ltd.).

Figure 3.33 Southwest Ethiopia: Grass cutting by machete Machetes are used almost universally to cut brush and grass in Equatorial Africa. There are no draft animals in this area because of the prevalence of trypanosomiasis (carried by the tsetse fly) and other serious livestock diseases. This grass is used primarily for roof thatching. (AFR-68)

e) Digging Forks and Hooks Where animal-power is not available, root crops like groundnuts, yams, cassava, potatoes, beets, must be dug out with hand tools. Digging forks or hooks made by local blacksmiths are used but imports with strong durable teeth are needed to withstand the very hard ground.

f) Maize Husking Tools Most hand farmers rip off the husks and break the ear from the stalk with their bare hands. Often the stalks are cut off close to the ground with a machete and piled before husking out the ears. A few maize farmers in Ghana and Tanzania use a metal hook to rip open tough husks. Special husking gloves with a metal palm hook were not seen in use.

g) Small Grain Threshers Hand farmers use simple flailing sticks 3 to 5 cm. in diameter and from 1 to 2 m. long to beat the kernels out of the heads. The grain is normally spread out on a special threshing floor of hardened mud or well-trampled and consolidated soil. More elaborate flails like the Chinese rotating-end-flail were not observed in Equatorial Africa.

Since rice is a relatively new crop in Africa, threshing-gates or sleds have apparently not been introduced. Although barley, wheat and flax are tied in sheaves, they are not threshed by beating the heads against slanted gates because they are more difficult to thresh. This is particularly true for the new high-yield varieties like Kenya I wheat.

Pedal-operated or hand-operated drum threshers, common in Asian rice-growing countries, are rarely used in Equatorial Africa. A few models have been brought in for trial by the governments of Ghana, Nigeria, Ethiopia, Kenya and Tanzania, but so far they have not been actively promoted by the agricultural extension services. In general, commercial farms are unwilling to sell, service, and distribute drum threshers unless there is sufficient demand from farmers and strong support from government advisory services.

With more rice being grown in western Africa, and increased interest in eastern Africa, there is a place for a small hand-operated grain thresher which can be adopted to engine-power later. A typical machine has a revolving drum fitted with teeth or bars driven by a connecting rod and crank at a speed of 300 to 400 rpm. The grain heads are held against the revolving drum until the grain is beaten out. The machines are relatively inexpensive, portable, and light (35 to 80 kg.) but according to Hopfen, they are "satisfactory only when the grain is easily detachable from the stalks, as with rice, but not wheat or barley." In another type of drum threshers "the whole wheat is passed through the machine but the man-power needed to operate it is high."[112]

h) Maize Shellers Most hand farmers shell maize by rubbing two ears together or by rubbing one ear with a cob. Very few hand farmers own any processing equipment except the mortar and pestle used to prepare flour from whole grains.

A few small, single-ear crank-operated hand shellers for maize were seen in Kenya, Ethiopia, Ghana, and Nigeria. Most have been imported from India, United States, and Poland. The simplest version is a small cast iron model which is clamped on a box or board. A single ear fed into the throat is grabbed by a vertical rotating toothed disk and rolled over a stationary shelling plate. The shelled corn drops out the bottom and the cob discharges from the side. A larger, more elaborate model, once very popular in the United States, has a feeder, vertical shelling disk, picker-wheel with teeth on the inside, a device for holding the ear against the shelling disk and possibly a winnowing fan and cleaning sieves. One model is available from England for about $40 at the factory.[113]

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[112] Hopfen, *op. cit.*, p. 123.

[113] *Tools for Progress 1967/68*, (London: Intermediate Technology Development Group, R. Hunt and Company, Ltd.)

1) Groundnut Shellers Quite a few groundnut shellers were observed in West Africa, but their use is not as wide spread as one might expect. The sheller has a semi-circular screen against which oscillating shelling bars crush the shells and allow the nuts to drop through the screen. (Figure 3.34.) Various screens are available and must be properly sized to prevent breaking the nuts. In northern Ghana, Yenli reported the shellers were not being used because the local groundnuts were extra large and damaged by undersize screens.[114] Although coarser mesh screens were said to be available through John Holt, Ltd., little emphasis was placed on using the sheller or fitting the correct screen size.

In northern Nigeria, Haynes said the only hand-operated machine in common use is the groundnut decorticator. Worked by one or two men, the decorticator rapidly removes the shells at a rate over 50 times faster than hand shelling. About half of the decorticators are made in Nigeria at about $36.00.[115]

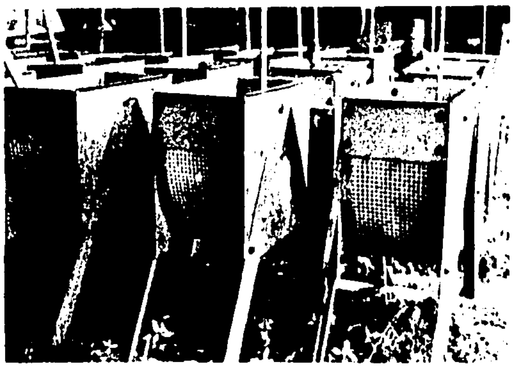

Figure 3.34 Mechanization centers have a variety of equipment including hand- and animal-powered tools These rocking action groundnut shellers were made in England and are satisfactory when correctly adjusted and the proper screen size is used. These units have been stored under cover and are still in good condition after 5 or 6 years. (AFR-262)

2) Power Required for Hand Harvesting and Threshing

Nearly all cutting, digging, husking, threshing, and winnowing

[114] Yenli, *op. cit.*, April, 1968.

[115] Haynes, "The Development of Agricultural Implements in Northern Nigeria," p. 23.

operations are carried out by individuals. They may work in groups, but each tool is used by one person. One-handed tools are the sickle, scythette, machete, maize and groundnut shellers and winnowing fans. Other tools require both hands such as the scythe, digging hoes and hooks, threshing-flails, drum threshers, and winnowing baskets.

a) Hand Digging Haynes studied labor requirements for lifting groundnuts for three different methods of planting. Planting in the flat not only gave the highest yields but required less labor to lift, clean, pick and shell. The labor required for lifting groundnuts with hand hoes in three experiments is shown in Table III.12. While the output of hand labor employed is low, the labor requirement is very high.[116]

TABLE III.12 LIFTING GROUNDNUTS WITH HAND HOES: NORTHERN NIGERIA

Site	Samaru	Samaru	Kano
Method of planting	Ridge	Flat on bed	Flat
Reference	NPG Trial[a]	Table III[a]	Table V[a]
Average yield kg. per hectare	1162	643	1285
Lifting, man-days per hectare	139.0	117.8	77.1
Cleaning, woman-days per hectare	73.1	88.2	29.6
Picking, woman-days per hectare	197.3	294.0	29.6
Shelling, woman-days per hectare			74.1
Total days per hectare	409.4	500.0	210.4

[a]Haynes, A *Brief Review of Mechanization Experiments in Northern Nigeria*, pp. 16-17.

b) Hand Threshing In threshing upland rice yielding 1683 kgs. per hectare, Haynes reported:

> It required 98 woman-hours per acre [242 woman-hours per hectare] by the traditional methods. Simple hinged-flails did not speed up the work, but four men, using a tong (a threshing box containing a ladder against which the rice heads are beaten), took 80 man-hours per acre [197.5 man-hours per hectare]; the men, however, were loathe to undertake what they considered to be women's work.[117]

[116]Haynes, A *Brief Review of Mechanization Experiments in Northern Nigeria*, p. 16.

[117]*Ibid.*, p. 17.

c) Drum Threshers Most pedal-operated and hand-operated drum threshers are very tiring to operate. Two operators can take turns running the machine to allow for rest. With some threshers both men can work together. The hand-operated drum thresher requires high manpower for operation and Hopfen says, "it seems to have few if any advantages over indigenous appliances described earlier."[118]

d) Groundnut Decorticators Haynes tested various types of groundnut decorticators and says:

> The normal hand-operated types have a throughput of about 300 to 350 lbs. [136 to 159 kgs.] per hour, but the time [per hectare] for the whole operation varies greatly depending on the strength of the wind for winnowing the mixture of shells and nuts. The power required is about 0.14 h.p., which is more than the average man can develop continuously, and a shift of two men working is normal.
>
> Simple stripping-tables reduce the time required for picking nuts by about one-third but are not popular with the women workers, who prefer to sit at their work.[119]

3) Time and Labor Required for Hand Harvesting and Threshing

a) Sickle Mowing Harvesting small grains with a sickle is very slow work. In eastern Africa farmers often work in groups of two to eight when harvesting crops. Gabathuler reported that with Ethiopian sickles, "the amount of work per hour is about 80 to 100 m.^{2}"[120] Sommerauer, in a time and motion study in Afghanistan, recorded similar results in mowing wheat in two studies showing "the rate of work was 129 m.^{2} per man-hour. . . . This figure is, no doubt, rather near the upper limit of the working capacity and would therefore be too high as a standard for continuous work."[121] It should be noted that when using the sickle for cutting small grains or grass, the men usually work in a squatting position in Africa as well as in Asia.

For mowing grass with a sickle, Hopfen indicates a work-rate of about 100 m.^{2} per man-hour. He says, "green crops can be cut five times faster with a scythe than with a sickle. About 500 m.^{2} can be mown in one hour, provided the land is flat and free from stones."[122] Thus for mowing grass or forage crops, the sickle is slow with a comparative work-rate of only about 20 percent.

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118 Hopfen, *op. cit.*, p. 123.

119 Haynes, *A Brief Review of Mechanization Experiments in Northern Nigeria*, p. 17.

120 Gabathuler, *op. cit.*, p. 5.

121 Sommerauer, *op. cit.*, p. 5.

122 Hopfen, *op. cit.*, p. 112.

b) <u>Scythe Reaping</u> Hopfen states, "Grain can be reaped with a cradle three times faster than with a sickle on flat fields with uniformly standing crops."[123]

Gabathuler says, "The area that can be mown with a scythe is about 500 $m.^2$ per hour when cutting grass for hay production, and about 300 $m.^2$ per hour when cutting cereals . . . from three to six times as much as with a sickle."[124]

Sommerauer reports, "If we calculate the mowing performance of a sickle as 100 $m.^2$ per man-hour . . . the efficiency of scythes as compared with that of sickles would be 5:1 for mowing green crops, 3:1 for mowing grain with a cradle; and 2 to 2.5:1 for mowing grain with the usual scythe, including gathering."[125]

c) <u>Hand Picking</u> In Nigeria, Haynes reported labor required for cotton harvesting by hand (two pickings) in the spraying trials at Makwa averaged 79.3 and 80.3 man-days per hectare. The yield of seed cotton was 1142 and 1468 kgs. per hectare, respectively.[126]

In Ethiopia, a study was made of newly settled Afars picking cotton for the first time, January, 1968. For this survey five people were selected, two men and two women in their late thirties and one man twenty years of age. They picked a total of 926 kgs. of seed cotton in seven days, averaging 26.45 kgs. per person per day. On the average, each person picked 3.5 kg. per hour which may be high, since they were doing their job more carefully than normal.[127]

4) Skill and Management Required

The scythe is a more efficient tool for mowing than the sickle, but it requires more skill and attention to use and keep sharp. Ground blades are subject to breakage but mild steel blades must be hammered. Hopfen points out, "scythe hammering is difficult and skilled work . . . It takes about half-an-hour to sharpen a scythe blade properly."[128] Also, the land must be flat and free from stones to permit the scythe to be used efficiently.

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[123] *Ibid.*

[124] Gabathuler, *op. cit.*, p. 9.

[125] Sommerauer, *op. cit.*, p. 12.

[126] Haynes, A *Brief Review of Mechanization Experiments in Northern Nigeria*, p. 15.

[127] Seyoum Solomon, Research Assistant, Institute of Agricultural Research, Addis Ababa, Ethiopia, Personal Communication, February, 1968.

[128] Hopfen, *op. cit.*, p. 107.

Both Gabathuler and Sommerauer, who introduced scythes into Ethiopia and Afghanistan, reported that the farmers learned quickly and became quite expert in handling them.[129] Most farmers can use it without prolonged instruction.[130]

One problem with any equipment is keeping it properly adjusted. With simple fixed-blade tools, the farmer simply adjusts himself to them and develops skill and dexterity. Simple machines like groundnut decorticators and pedal-or hand-operated threshers, however, require special skills to keep them in adjustment. Haynes reported such a difficulty with the correct adjustment of groundnut decorticators.

> Decorticators which are not properly set are difficult to use and break many of the nuts. While no special skill is needed to make the adjustments, it requires patience and the proper tools: one set of spanners, one silver gauge and one packet of grease. The beater bars must be set so they are just over one-half inch from the slotted-concave and at the correct angle to it. This is checked simply with the silver gauge. The gauge is pushed under each bar in turn and the bars pressed down until they rest on the gauge.

Haynes emphasizes:

> Tighten all the bar nuts TAKING CARE NOT TO MOVE THE BARS . . . CHECK EACH BAR WITH THE GAUGE AGAIN! If it is found that the bars are not correct, they must be readjusted. At first it may take an hour to adjust one decorticator. All this time is wasted if even one bar is too close to the concave.[131]

5) Costs Involved

Based on the time and labor data given for the various hand tools and implements and the previously suggested wage rates for Ethiopia and Nigeria, the following costs can be determined for selected hand-powered agricultural operations in these two countries. To avoid the complication of assuming different wage rates, these data are also given in man-hours per hectare.

Animal Harvesting Operations

1) Introduction

In areas of Equatorial Africa where animal power is used, most harvesting is still done by hand. Animal-drawn implements are used basically

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[129] Gabathuler, *op. cit.*, p. 9.

[130] Sommerauer, *op. cit.*, p. 12.

[131] D.W.M. Haynes, *Interim Report on Tests on Ox-drawn Implements as Groundnut Lifters* (mimeographed) (Zaria, Nigeria: Second Meeting of Agricultural Engineers, November, 1964), pp. 24-27.

TABLE III. 13 WORK RATES AND COSTS FOR SELECTED HAND HARVESTING OPERATIONS: ETHIOPIA AND NIGERIA

Operation	Tool	Average work rate	Man-hours per ha.	Cost per man-hr.	Cost per ha.
				dollars	dollars
Ethiopia					
Mowing grass	Sickle	80 $m.^2$/man-hour	125	0.05	6.25
Reaping grain	Sickle	100 $m.^2$/man-hour	100	.05	5.00
Mowing forage	Scythe	500 $m.^2$/man-hour	20	.05	1.00
Cutting grain	Scythe with cradle	300 $m.^2$/man-hour	33.3	.05	1.67
Pounding grain	Mortar & pestle	1 kg./woman-hour= 1000 kg./125 days	-	.08½	82.50/ 1000 kg.
Nigeria					
Picking cotton	Hand	80 man-day/ha.	640	.11	70.40
Digging groundnuts					
" on the ridge	Hoe	139 man-day/ha.	1390	.11	155.90
" in flat bed	Hoe	118 man-day/ha.	1180	.11	129.80
" on flat	Hoe	77.1 man-day/ha.	771	.11	84.81
Shelling groundnuts	Hand	55.7 man-day/ha.	557	.11	61.27
Threshing rice	Hand sticks	182 man-hours/ha.	182	.11	20.02
Threshing rice	Tong ladder	198 man-hours/ha.	198	.11	21.78

for only one operation in western Africa, lifting groundnuts. Otherwise, the small farmer does all of his harvesting by hand, including digging yams, cassava and potatoes with a hoe, hook or spade; cutting off the heads or stalks of sorghum, millet, guinea corn, sugar cane and maize with a knife or machete; husking maize by hand; picking cotton, cocoa beans, peas, palm-nuts and other bush and tree crops by hand; cutting small grains such as rice and wheat with a sickle, and cutting specialized fibre-crops like *kenaf* with a special machete.

Forage crops of alfalfa and clovers are seldom grown. Short grasses are cut with a grass sickle, and tall rank-growth, such as elephant-grass, is whacked down with a machete. Burning is still a common practice observed extensively in October in northern Ghana and Nigeria, and in southwestern and southern Ethiopia, to get rid of unwanted vegetation after harvest or before tillage.

In eastern Africa and particularly in Ethiopia, cattle, but not implements, are used almost exclusively by animal-powered farmers to thresh small grains. Animals are not used directly in other harvesting or threshing operations, except to move bundles of grain from the fields to the threshing floor, or to haul straw into town for sale. Nearly all products are hauled on the backs of animals, except for a few sleds used in the fields and carts for transport near towns and larger cities. The animal-powered farmer cuts

his wheat, barley, flax, sesame, rice and *teff* with a sickle; husks his maize by hand; cuts the heads or stalks of sorghum, millet and maize with a machete; picks cotton, coffee, tea, pyrethrum by hand; and slices off the sugar stalk or sisal leaves with a special machete. In a few areas a limited threshing service may be offered by settlements, cooperative farms, agricultural research stations, private hire-services or large farmers to a few nearby farmers. But for the most part, the small farmer is strictly dependent on his own hands and the hooves of his animals.

a) Cutting and Harvesting Implements The animal-drawn mower, used extensively for cutting green forage and hay crops for livestock in temperate regions, is not found on African small farms. The mower with a buncher, the reaper with a gathering platform and the binder with the automatic bundle-tyer are equally scarce. Even the simple animal-drawn maize cutting sled is not used in Equatorial Africa.

b) Threshing and Decorticating Machines The threshing sled common to Asia and the Middle East is an unknown device in Equatorial Africa, as well as the threshing roller pulled by animals in the Near East, Pakistan, India, Spain and Portugal. When animals are not available to thresh grain by trampling, the grain is beaten out with sticks or rubbed out by hand. *There is a great shortage of animal-powered equipment available for harvesting or threshing in Equatorial Africa.*

Admittedly, costs in Africa to transform linear animal motion into rotary-power for operating stationary threshers, processing equipment and decorticators forestall popular use. This can best be performed on a community-wide basis today by one or more engine-powered units. The present state of small internal combustion engines development is too far advanced to justify costly investment in less efficient animal-powered stationary power units. But the bulk of the emerging animal-powered farmers' field harvesting operations await improved animal implements.

c) Transportation and Hauling Equipment This is an important part of harvesting operations long neglected for the African animal-powered farmer. Suitable carts at prices the small cultivator could afford, would probably become the most used piece of animal-powered equipment on the African farm, as they have in most other advanced animal-powered areas of the world.

1) Tools and Practices

a) Digging Methods and Tools The groundnut lifter is the most important animal-powered harvesting machine in western Africa. It is obtainable as a special purpose tool or as an attachment for a multiple-

purpose toolbar, toolframe or basic plow. A number of tests have been conducted in Nigeria to evaluate manufactured lifters currently available, and to develop new-type lifters for especially difficult soil conditions. Haynes reported in 1964 that the most favored ox-drawn lifters (Ariana, Samaru lifter and Kano Ring) reduced the hand labor requirement in half, and the other satisfactory ones (Emcot, Samaru Multiple-Purpose, Sine and Arara) reduced the labor by one-third.[132]

The basic chassis toolframe of the Ariana groundnut lifter is mounted on skids or wheels to which is attached the heavy-duty groundnut digger-blade. The shank is offset to the left so that the vines pass straight back without obstruction. The unit straddles ridges readily and has good penetration. Haynes said the Ariana showed great promise in western Africa as a multi-purpose animal toolframe and the lifter was one of the best tested. The machine was easy to control and could be handled by one man.[133] (Figure 3.35.)

The Arara groundnut lifter is made by SISCOMA under license from Arara Manufacturers in France. Originally assembled from imported parts from France, it is now completely fabricated in the Senegalese factory. Basically it is designed as a groundnut lifter convertable into a hoe, moldboard plow or ridging plow. Weighing 23 to 24 kgs., it consists of a heavy rectangular hollow beam to which are attached simple V-shaped handles and a strong standard carrying a duck-foot blade. The blades come in three width of 20, 35 and 50 cm. and are symmetrically mounted to travel down the center of the row.

The Sine 7 hoe with groundnut lifter is designed as a hoe; the frame is much lighter but can be used with the same lifter attachment supplied on the Arara. (Figure 3.15.) A special adapter and chain are needed to attach the heavy standard to the smaller Sine frame. The lifting blades are identical. It is made under license from Mouzon Nolle.

The APLOS Mark IV toolbar with lifter attachment is a horizontal knife blade about 40 cm. long supported on each end to form a U. It is fastened to the rear of the lift frame of the toolbar by clamps which permit vertical or horizontal adjustment. (Figure 3.36.) The unit straddles the row and is said to have good penetrating and lift characteristics. No test results have been published.

As now used by farmers, the Emcot plow as a groundnut lifter is the basic ridging plow with the right and left moldboards and wings removed.

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[132] *Ibid.*, p. 56.

[133] *Ibid.*, p. 57.

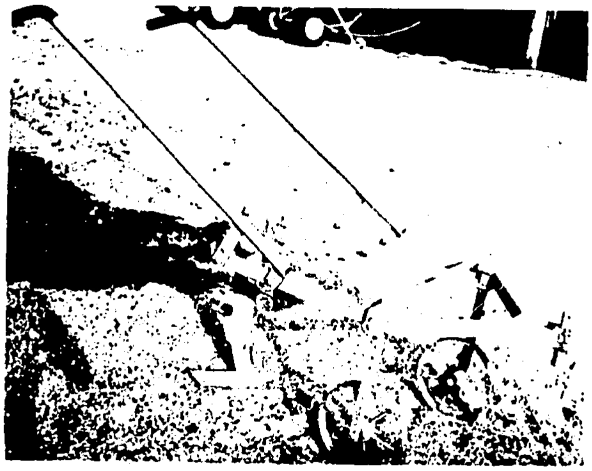

Figure 3.35 Ariana (French) multi-purpose tool frame with groundnut lifter and wheels One of the least expensive improved tools designed for modern animal power, this versatile tool carrier can perform all basic tillage and cultivation operations. It can also be equipped with a seeder or a groundnut lifter as shown here. This implement and its attachments are being manufactured in both eastern and western Equatorial Africa. Relatively few sales have been made so far, however, because even the cost of this tool when produced in small numbers is prohibitive to subsistence level farmers; and the cost of its introduction is great to developing countries. (AFR-299)

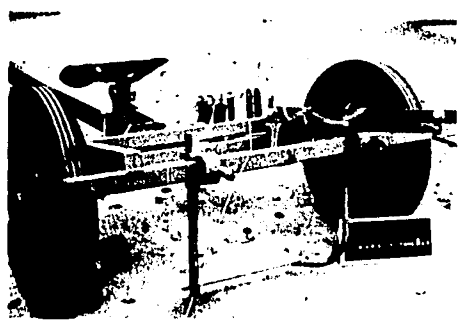

Figure 3.36 APLOS (British) multi-purpose toolbar with groundnut lifter Patterned after the design developed by the NIAE, this wheeled toolbar adds another dimension of mobility to the usefulness of multi-purpose animal-drawn tools. It can be equipped with either a forward or rear positioned lifting lever to permit the operator to either ride in front or walk behind the soil and plant manipulatory parts. The manufacturer offers other improved implements such as ridger, and a chassis for an ox cart. (AFR-515)

The point and shin are used to rip open the ground to make it easier to finish digging out the nuts. More gleaning-time is required than for specially designed lifters. While an inexpensive substitute for the small Nigerian farmer already possessing this ridger, it is more difficult and fatiguing to handle.[134]

The Emcot plow groundnut lifter attachment is a special offset blade which is bolted to the tip of the plow-beam in place of the ridging body. Two versions are currently available. One made by Ransome is an extra-long horizontal blade offset to the right. On the model seen, no provision was made to overcome side-draft and the blade looked exceedingly long. Sales, distribution and acceptance are not known.

A prototype model of a special adapter and blade assembly developed in northern Nigeria is shown in Figure 3.37. This unit has been developed by Shambaugh with the Industrial Development Center of Zaria, to be made by local blacksmiths. A heavy 35 cm. blade is offset to the right and bolted onto the beam. A cross-bar with built-up ends is bolted to the front of the plow-beam. To this is attached a pair of wheel standards on each end to carry the regular ridging-plow depth-control wheels. A brace from the hitch center line of draft back to beam rear offsets side-draft. With over 60,000 Emcot ridgers in northern Nigeria, this attachment offers a good opportunity to expand the capability of farmers already using animal-power.[135]

The Samaru lifter is a special purpose low-profile lifter supported on two rear wheels straddling the row developed by the Agricultural Engineering Section at the Institute for Agricultural Research, Ahmadu Bello University, Zaria, Northern Nigeria. It proved to be one of the best lifters in tests but was expensive (ten times as high as the Kano Ring) and the Institute was not able to interest anyone in manufacturing it. Only a few were made and none are being sold today. It can be handled by one man and the working rate was the best of all lifters at 0.3 hectares per hour.[136]

The Samaru multi-purpose lifter is similar to the model above designed to take a variety of attachments. It was built in limited quantities for trials by Project Equipment Ltd., Salisbury, Wiltshire, England. The frame is offset to the right so nuts and vines spill over the back. It

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[134] *Ibid.*, p. 58.

[135] Shambaugh, *Summary of the Development in Progressive Mechanization for the Hand and Mixed Farmers in the Savannah Zone of Northern Nigeria*, p. 19.

[136] Haynes, *Interim Report on Tests on Ox-drawn Implements as Groundnut Lifters*, p. 56.

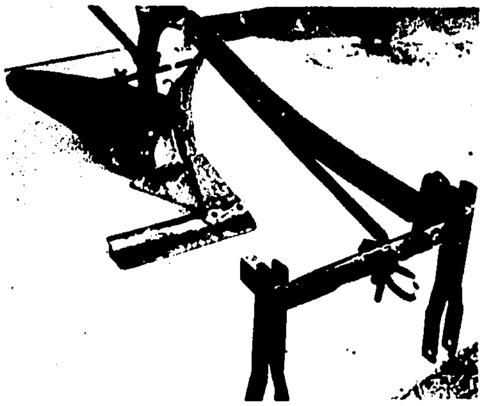

Figure 3.37 Shambaugh groundnut lifter attachment for the Emcot Ridger
Since there are already so many (over 60,000 units) Emcot ridgers in northern Nigeria, there is a big opportunity to change the present system of lifting groundnuts with the Emcot minus its winged moldboards. This attachment bolts onto the plow beam in place of the ridging plow and converts the Emcot into an effective groundnut lifter at relatively low cost. The Industrial Development Center with which Shambaugh is affiliated has begun to hold special in-service training schools to teach village blacksmiths how to make, repair, and service the attachment. (AFR-512)

is pulled with a short chain attached to a short tongue.

The Kano ring-lifter, built in small quantities by the Kano Native Authority, Kano, northern Nigeria, was designed to overcome regional soil conditions. It did not perform as well in some other areas. Basically, it is a large hoop positioned so the bottom quadrant runs underground and scoops out the ridge. It was expensive to make, requiring special steel for the ring. Time was needed to clear blockages and the soil was not disturbed as much requiring more hand shaking to separate the nuts from the dirt. The average measured draft was 102 to 125 kg. pull.[137] The price was about $14.00.

b) Threshing Methods and Implements In Ethiopia, nearly all grain threshing is done by animal trampling, often on special open-air threshing floors. Animals are also used in parts of Kenya and Tanzania where animal farming is traditional; and in Ghana and Nigeria to a very limited extent. Leander describes the method:

> Threshing is normally carried out during the dry months of December and January. The work can be divided into four separate phases:
> Phase 1: The present custom of threshing the grain is

[137] *Ibid.*, p. 57.

and cows) over the harvested grain shocks placed in a circle on the bare earth. [Figure 3.38.]

Phase 2: With the help of a fork-like tool of wood, the straw is separated from the grain heads.

Phase 3: The oxen are once again driven over the threshing place, now in order to thresh out the grain from the heads.

Phase 4: The chaff is now separated from the grain with a grain shovel made of wood.[138]

Huffnagel writes:

> Wooden forks and shovels 50 to 60 cms. in length and 20 to 25 cms. in width with 60 to 70 cms. handles are used to toss the grain into the wind and to sort out the chaff and straw from the grain. A further cleaning operation is performed with sieves and bowls.[139]

Figure 3.38 Threshing in Ethiopia In Chilalo Awraja threshing is done almost entirely by driving cattle over the loosened bundles of grain. After separation the grain and chaff is cleaned by winnowing the mixture by hand in the wind. The daily output of such a system is about 250 to 350 kgs. of uncleane grain. This work, which continues for 1.5 to 2 months, strains the oxen and many deaths are reported. (AFR-54)

Wind cleaning also is accomplished by giving a light and continuous movement to a grain-filled basket held chest high to let the grain drop and the chaff blow away.[140]

[138] Leander, *op. cit.*, p. 42.

[139] Huffnagel, *op. cit.*, p. 161.

[140] *Ibid.*, p. 146.

Bengtsson reported that insect damage is related to broken seed, and says:

> Seed damage by insects is observed but to a less degree than usually claimed. The threshing method influences the amount of broken seeds and the use of a threshing machine has last year given ten times as many broken seeds as the traditional method (threshing by oxen).[141]

An improvement over animal hoofs is the addition of a very simple rub-bar thresher using the ground as a stationary plate. Undoubtedly such devices are used in Equatorial Africa but the Team saw none during its travels. *For the low income farmer in Ethiopia, there is certainly room for this simple improvement and it could be made and promoted without much cost.* Turkey, in fact, reported 2.33 million sleds in use in 1966.[142] Hopfen describes this device as:

> . . . an animal-drawn implement consisting of two wooden boards, slightly raised in front, which are fitted with short pegs, serrated knives or hard stones, inserted into holes on the underside of the boards. The operator stands on the implement, to add weight, and this is dragged over the crop spread on the floor, the knives or pegs rubbing out the grain and bruising the straw.[143]

A more efficient animal-powered thresher has been developed for use in Portugal, Spain, Egypt and India. It is patterned after an old stone-roller threshing cylinder, which probably originated in China. While threshing rollers and disks are used in southern Europe, northern Africa and the Near East, they have not been introduced into the small-grain growing countries of eastern Africa, surveyed by this Study. The machine consists of a ribbed-roller or two or three rows of partially meshed disks mounted on a frame. It is pulled by animals over the grain spread on a threshing floor. Hopfen says:

> The disk thresher, known as the *norag* in the Near East, has iron disks about 45 cms. in diameter and about 15 cms. apart, with a seat and is drawn by a pair of animals. The crop is spread in layers 30 to 50 cm. deep and is turned over with wooden forks while being threshed. The grain obtained is not clean and has to be separated not only from chaff but also from dust and dirt. Grain is also likely to be broken and some not threshed or eaten by the draft animals. The whole process is rather slow, but it has the advantage that the straw is bruised.[144]

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[141] Bengtsson, *op. cit.*, p. 60.

[142] Central Treaty Organization, *op. cit.*, p. 36.

[143] Hopfen, *op. cit.*, p. 120.

[144] *Ibid.*, pp. 120-123.

In India, a special rolling-thresher, the "Olpad Thresher", consists of a frame with two or three axles on which are mounted 8 to 20 toothed and ribbed 45 cm. diameter disks with 15 cm. cast-iron spacers between. The disks made of 10 gauge steel sheet pulverize the straw and separate the grain. In operation, the machine is pulled around the circle of straw on the threshing floor. (Figure 3.39.) Constantinesco says, "*It is considered five times faster in separating grain from the ears than the old trampling method.*"[145] Well designed models have safety guards over the disks to prevent injury to the operator, and to provide him with a comfortable seat and back-rest. An extra raking attachment can be fitted behind for stirring the straw during threshing. Threshers made by one manufacturer (Cossul) are available in 8, 11, 14 and 20 disk sizes and weigh 92, 110, 125 and 190 kg., respectively. Capacity varies according to weight and number of disks. *In the small grain areas of eastern Africa, the rolling-disk thresher could have a tremendous impact on the farming methods and attitudes of traditional subsistence farmers now threshing with animal trampling.*

c) Cutting Methods and Implements The oscillating cutter-bar mower, used extensively in the temperate region for cutting forage, hay and green crops, is virtually unknown in Equatorial Africa. Experiment stations and settlement farms have a few, but the traditional farmer has little use for it. Since he grazes his animals and has very small fields, he is not accustomed to making hay for livestock. With his rudimentary knowledge of machinery and lack of experience in properly adjusting close-fitting parts, he would have more than the usual trouble with this complicated piece of animal-powered machinery. Hopfen suggests, "Where labor is abundant and rather cheap, the introduction of the animal-drawn mower is unnecessary, especially in areas where the released labor cannot be employed to advantage elsewhere."[146]

The mower used for harvesting cereals, the reaper for cutting and windrowing grain, and the binder for cutting and automatically bundling sheaves are not found in the traditional animal-farming areas of Equatorial Africa. These machines are all more complicated than a mower, and with the present limited demand, high costs of production , deficient mechanical background

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[145] I. Constantinesco, *Report on a Visit to the Far East to Study Indigenous and Improved Farm Implements and Machinery for Small Peasant Farmers in the Tropics*, (mimeographed) (Rome: Food and Agricultural Organization of the United Nations, 1961), p. 10.

[146] Hopfen, *op. cit.*, p. 115.

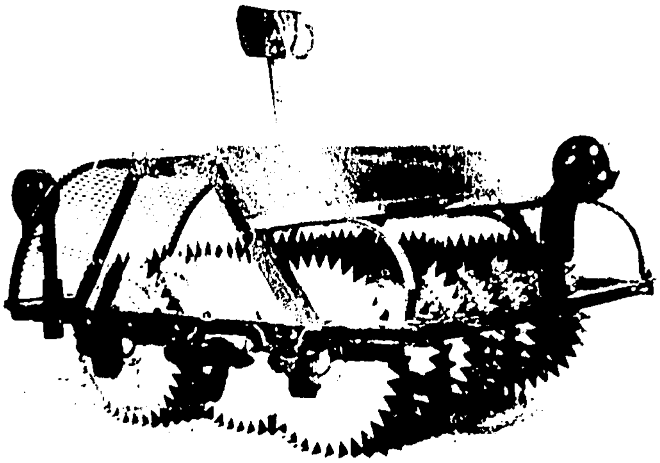

Figure 3.39 Olpad (Indian) thresher for threshing grain with animal power Compared to trampling out the grain with hooves, this simple machine can greatly accelerate the task of threshing small grains where animals are the traditional source of power. The machine is pulled over the sheaves by an ox team and parallel sets of disks rub out the grain. The straw is turned by men with forks or it may be stirred by an attachment fixed to the rear of the device. The grain must be cleaned after it is separated. (Photo courtesy of N.C. Khanna, Cossul and Co. Pvt. Ltd., Kanpur, India)

and lack of supporting services they probably will not be used to any great extent in Equatorial Africa.

The Mouzon Frères Company of France manufactures a reaping machine for developing countries consisting of a two-wheel cart equipped with a 1.5 meter sickle-bar cutter. The cutter bar, mounted just in front of the right wheel, is ground driven.

2) Output, Power, Time and Labor Required

a) Groundnut-Lifters The power, lifter-capacity and man-hours required to dig and glean groundnuts with different ox-drawn lifters is given in Table III. 14. This series of trials was carried out in cooperation with the Kano Agricultural Research Station during October, 1964, to determine the extent to which damage occurring during lifting influenced the development of aflatoxin in groundnuts. Three implements of different characteristics were compared with two methods of hand lifting during the main trial. The opportunity was taken to test four other implements at the same time. The report dealt only with mechanical performance of ox-machines.

TABLE III. 14 EFFECTIVENESS OF GROUNDNUT LIFTERS: KANO, NORTHERN NIGERIA 1964[a]

Make	Power	Lifter digging	Capacity	Total labor required[b]	Damage to nuts by wt.	Nuts left as gleaning by wt.
		hrs./ha.	ha./hr.	man-hours	percent	percent
Samaru Lifter	Ox-drawn	3.36	.30	41.0	.74	9.13
Ariana Multi-purpose	Ox-drawn	3.56	.28	45.2	.71	10.74
Sine Lifter	Ox-drawn	4.59	.22	47.5	.66	14.12
Emcot Ridger	Ox-drawn	6.02	.17	26.7	n.a.	n.a.
Kano NA Ring Lifter	Ox-drawn	3.85	.26	52.5	1.01	9.56
Arara Lifter	Ox-drawn	5.14	.19	55.6	1.33	14.51
Samaru Multi-purpose (Project Equipment Ltd.)	Ox-drawn	4.27	.2[illegible]	62.1	.77	8.58
Hand Lifting	Man	-	.024	86.5 to 93.8	1.75	8.23

[a]Haynes, *Interim Report on Tests of Ox-drawn Implements as Groundnut Lifters*, p. 59.

[b]Labor for hand wind-rowing.

On working rates Haynes concluded:

> The implements fell into two distinct classes, those straddling the row, which averaged [0.28 ha./hour] and those running down the centre of the row, averaging [0.19 ha./hour] intermediate, with a working rate of [0.234 ha./hour] per hour. A direct comparison was possible since the Ariana (straddling the row) and Sine (centre of row) used the same soil-working parts: in a given time, the Ariana lifted 29.2 percent more acreage.[147]

In another test, a comparison was made between the standard Emcot ridging plow modified for lifting and a special purpose lifter. Table III. 15 shows the comparison; man-days are about double for the Emcot, while the gleaning times are over four times as high.

TABLE III. 15 COMPARISON OF TWO OX-DRAWN IMPLEMENTS FOR LIFTING GROUNDNUTS: NORTHERN NIGERIA[a]

		Emcot Plow[b]		Samaru Lifter	
Operation	Laborer	Days per hectare	Hours per hectare	Days per hectare	Hours per hectare
Lifting	Cattle & Plowman	4.2	33.6	2.1	16.4
	Man	8.[illegible]	67.2	4.0	31.6
Gleaning	Woman	133.0	1064.0	28.9	231.0

[a]Haynes, *A Brief Review of Mechanization Experiments in Northern Nigeria*, p. 16

[b]Standard ridger with moldboards removed.

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[147]*Ibid.*, p. 61.

b) <u>Threshers</u> In south central Ethiopia, an average farmer can thresh 200 to 250 kgs. of grain per eight-hour day using 4 to 8 oxen and at least 2 men. One man drives the oxen around in a circle and the other loosens and turns over the trampled straw after the oxen pass over the spot several tim . The men generally take turns with their jobs.

The threshing is done in small batches yielding 100 to 150 kgs. depending on the quality of grain. With the old native varieties of wheat and barley, one batch can be trampled in 2 1/2 to 3 hours, but farmers complain the new high-yielding varieties like Kenya I, take about 4 hours, or from 40 to 60 percent longer. For this reason, farmers like Kenya Supreme which threshes a little easier.[148]

Gabathuler reported:

> Most of the threshing is done by oxen trampling the outspread sheaves until the grain drops out . . . The output of a three-man team with four oxen is approximately 200 to 350 kgs. per day.[149]

An FMC International Study team in 1967 reported:

> Grain harvesting and threshing require at least two months and transport to market takes another month. Because of lack of storage . . . prices fall just as harvesting begins.[150]

A simple threshing sled probably would increase threshing efficiency from 150 to 200 percent or give a rate of 300 to 500 kgs./day with 4 oxen and 3 men. Normally, one pair of oxen is used at a time but, since this is strenuous work for them during the dry season. they are alternately worked and rested.

One manufacturer of the Olpad thresher reports a daily output of 350 kgs. for an eight-disk thresher to 850 kgs. for a 20-disk model. These rates depend on the quality of grain, the amount of straw, the variety and ease of separation, as well as on the energy of the operators and livestock. At this rate the Olpad is about 50 percent faster for the smallest size, up to 3 to 4 times faster for the largest size.

3) Skill and Management Required

a) <u>Groundnut-Lifting</u> The Kano Agricultural Research Station made

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[148] L. Ohlsson, Extension and Adult Education Advisor, Chilalo Agricultural Development Unit, Addis Ababa, Ethiopia, Personal Communication, March, 1968.

[149] Gabathuler, *op. cit.*, p. 6.

[150] FMC Report to USAID, *Agricultural Development: Potential for Investment in Morocco, Kenya and Ethiopia* (San Jose: FMC International, September, 1967), p. C-14.

these suggestions:[151]

1. To help in controlling fungal infection, it is important to lift groundnuts at the correct time with as little damage as possible.

2. Where the Emcot or any other implement is used, the plowman must throw debris from blockages to the side to avoid crushing of the nuts by cattle on subsequent rounds.

3. Implements which straddle the row are markedly more efficient (about 30 percent) than those working down the center of the row.

4. It is unlikely that machines cause significantly more damage than hand digging when the machines are used properly.

5. For proper drying, it is recommended that the vines and nuts be inverted on top of the ground, requiring about 10 to 15 percent more time than normal for shaking and laying the vines flat on the ground.

b) Threshing with Animals Skill and energy are needed to keep cows moving on an open-air threshing floor. Usually the best trained ox is used as the pivot in the center of the ring, and the other animals circle around him. In some areas, animals are reported to be lashed together. Care must be taken not to underthresh new varieties contributing to high losses or to overthresh it to crack or damage the kernels. Farmers should know the threshing characteristics of each major variety, how much straw should be cut with the grain, how dry it should be before threshing and how long it takes to thresh it out. Precautions must be taken to select and prepare the threshing floor so that dirt, stones and debris do not contaminate the grain or increase losses and make it difficult to clean. Oxen that scavenge for feed during the dry season are not in the best condition and caution must be exercised to avoid overworking them. A number of cattle deaths occur due to strain during the long threshing season. The threshing season may last 2 to 3 months and with increased yields from new harder-to-thresh varieties, the grain will be exposed more to weather hazards and to insect and rodent attacks unless more efficient threshing methods are adopted.

5) Costs Involved

a) Groundnut Lifting Few detailed cost analysis studies have been made on animal-powered crop-production operations. Since animal-power is always combined with a large amount of hand-power (generally referred to as

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[151] Haynes, *Interim Report on Tests of Ox-drawn Implements as Groundnut Lifters*, p. 62.

mixed-farming), the total cost is largely dependent on the costs of hand-labor. For purposes of comparison in Table III. 16, a standard labor charge of $0.11 per hour for hand-labor, and a charge of $0.45 per hour for two oxen and a driver, is based on current rates in northern Nigeria.

TABLE III. 16 COSTS OF LIFTING AND HARVESTING GROUNDNUTS WITH ANIMAL AND HAND POWER: NORTHERN NIGERIA 1968[a]

Implement	Labor	Animal[b] digging	Hand labor[b] wind-rowing	Cost of animal power	Cost of hand-labor	Total Cost harvesting
		hrs./ha.	hrs./ha.	dollars	dollars	dollars/ha.
Samaru Ring	2 oxen	3.36	41.0	1.51	4.52	6.03
Ariana Mold-board Plow	2 oxen	3.55	45.2	1.61	4.97	6.57
Kano NA Ring	2 oxen	3.85	52.4	1.73	5.76	7.48
Samaru Mold-board Plow	2 oxen	4.27	62.3	1.93	6.82	8.75
Sine	2 oxen	4.59	47.4	2.08	5.22	7.29
Emcot Ridger	2 oxen	6.03	51.4	2.72	5.66	8.38
Hand Hoe	1 man	-	87 to 94[c]	-	9.52 to 10.33	9.52 to 10.33

[a]Hand-labor charge is $0.11 per hour based on hired labor charge. Animal-power charge is $3.60 per 8-hour day, based on custom charges for lifting.

[b]Data for hours extracted from Haynes, *Interim Report on Tests of Ox-drawn Implements as Groundnut Lifters*, p. 56.

[c]Digging is included in the labor for wind-rowing.

In another study, Moczarski computed the hours required by man, woman and cattle in producing groundnuts in a system with cattle used for ridging, earthing-up and lifting. The animal-harvesting operation took only three to five days per hectare, and accounted for $5.25 out of a total cost of $274.74, or roughly 2 percent.

In general, the use of animal-drawn implements reduces the labor requirements of lifting groundnuts by one-third to one-half.

b) Threshing with Oxen The traditional method of threshing small grains by trampling is used throughout Ethiopia and in certain other areas of Equatorial Africa wherever animals are traditionally worked. The information in Table III. 17 on trampling is based on observations in the Asella area of south central Ethiopia and on comments from farmers. The data on the improved methods is based on manufacturers' quotations on disk-thresher capacities and estimates of improved output with sled-devices. As the costs of labor and ox-power go up, there is greater advantage in more modern methods. Likewise, *as new, higher-yielding varieties are introduced, as more agricultural inputs are employed to intensify production, and as cropping areas are expanded, the greater is the comparative advantage of mechanical power and machine-assisted methods.*

TABLE III. 17 ESTIMATED COSTS OF THRESHING WHEAT WITH OXEN BY VARIOUS METHODS: ETHIOPIA
(Based on current average charges in the Central Highlands, 1968)

Threshing method	No. of men	No. of oxen	Time	Labor	Ox labor	Labor costs[a]	Ox labor costs	Machine Ownership costs	Total threshing cost	Quantity per batch	Cost per quintal
			hours	man-hours	ox hours	dollars	dollars	dollars	dollars	kilograms	dollars
Traditional way:											
1. Trampling native varieties	3	6[b] (5 to 8)	3	9	18	0.45	0.90[c]	n.a.	1.35	200	0.68
2. Trampling improved varieties[f]	3	6	4	12	24	0.60	1.20	n.a.	1.80	250	0.72
Possible improved ways:											
3. Threshing sled native varieties	3	4[e]	2½	7½	10	0.38	1.00[d]	homemade	1.38	300	0.37
4. Threshing sled-improved varieties[f]	3	4	3	9	12	0.45	1.20	homemade	1.65	350	0.41
5. Olpad thresher-native varieties	2	4[e]	2	4	8	0.20	0.80	.12[g]	1.12	400	0.28
6. Olpad thresher-improved varieties[f]	2	4	2½	5	10	0.25	1.00	.15	1.40	450	0.31

[a] Man labor charge based on rate $.40/8-hour day ($0.05 per hour).
[b] According to CADU's studies, the average farmer owns three oxen and the balance of the animals are cows, horses or bulls which follow the oxen. Thus, if a farmer uses three oxen and five cows, the charges for the cows would be approximately half that of the oxen.
[c] Ox-labor for trampling based on estimated wear-and-tear cost of 50 percent of normal working charge for plowing at $1.20 to $1.60 per 8-hour day for a pair of oxen and driver (0.075 to 0.10 per ox-hour). Cost charged at 50 percent, gives a cost of $0.04 to 0.05/ha., the higher figure is used.
[d] Ox-labor for pulling a sled or disk-thresher is based on regular charge of $1.20 to 1.60/day or 0.07½ to 0.10/hr., the higher figure is used.
[e] Regular oxen are used, and if farmer cannot borrow a fourth, he will have to let them rest more, prolonging the time to thresh out his grain.
[f] Improved varieties like Kenya I and Kenya Supreme adhere more tightly and are harder to thresh out.
[g] Based on a 20-disk thresher costing $120.00, used 240/hrs./year with 10-years' life. Depreciation equals 0.05/hr. plus 20 percent for repair and maintenance of 0.01/hr. for a total of 0.06/hr. for machine ownership costs.

Hand Operations

1) Tools and Practices

a) Winnowing Devices After threshing by beating with sticks, trampling with animals, or running through simple machines, the grain is very dirty and contaminated with large amounts of straw, chaff, weed and plant seeds and inert material. Hand-cleaning by shaking sieves, tossing the mixture into the air, or pouring it above the ground in the wind is a time-consuming and difficult task.

In Equatorial Africa, the most common method used by hand farmers is wind separation. Wooden forks are used to throw the straw into the air to separate it from the grain, chaff and small pieces of foreign material. (Figure 3.40.) Next, wooden shovels are employed to toss the grain and chaff mixture into the wind to separate the grain from the lighter fractions. To further clean the grain of any remaining weed seeds winnowing baskets and sieves are frequently used. Effective winnowing depends on sufficient wind to separate the materials. *Winnowing could be greatly speeded up by making artificial winds by hand with oscillating or rotating fans.* This process is sometimes used in Asia, but it was not observed in Equatorial Africa. Ma says, "when natural wind is not strong enough, farmers use a [rectangular] fan to blow air for cleaning." The fan is made with a bamboo frame and covered with cardboard over four-fifths of its surface. A strip along one side is left open for gripping with the hands.[152]

Baskets are used for cleaning small quantities of grain. A flat shell-shaped basket is shaken with a circular or forward and upward motion. The chaff and dirt work to the upper end of the basket and are discarded while the heavier grains are collecting on the lower side. The method produces a very clean sample and requires only simple equipment but, as Hopfen points out, "it is however extremely slow."[153]

Open-weave baskets are sometimes used as winnowing sieves. In use, the baskets are suspended from a tripod and shaken or stirred to move the grain downward through the mesh. Light chaff and foreign matter drop through to be blown away while heavy chaff and straw stay on top. The simplest

[152] F. C. Ma, *Preliminary Study of Farm Implements Used in Vietnam*, Chinese-American JCRR Plant Industry Series No. 24 (Taipei, Taiwan, China: April, 1963), pp. 171 and 41.

[153] Hopfen, *op. cit.*, p. 126.

Figure 3.40 Winnowing grain in Ethiopia A farmer in Chilalo Awraja is winnowing the grain from the straw by tossing it into the air with a wooden fork. This wheat had been threshed earlier that morning by trampling with animals for 3 to 4 hours. The farmer stated it would take him about a day to separate the coarse straw from the grain and chaff using this method seen commonly in the highlands of Ethiopia. For this work he will obtain 100 or 150 kg. of grain which still must be cleaned by women to remove the chaff from the grain. (AFR-150)

winnowing fan supplies an artificial wind to permit cleaning grain when there is not natural breeze. It is a 2, 3, 4 or 6-bladed wooden or metal fan mounted in a wooden housing, turned by hand crank, belt or chain. Bearings may be used from old cars, bicycles, or small trucks. While this method is rather tiresome and does not grade the grain, it is far superior to hand winnowing in the wind and could greatly expedite the cleaning of grain after threshing. Grading for size can be done later with hand sieves. While rarely used in Equatorial Africa, this method *has great potential for farmers who work together*. The fans can be built by trained local artisans or blacksmiths at low cost.

A more refined version of the winnowing fan has a high-capacity fan mounted in a wooden or sheet-metal housing. The air is drawn in along both sides of the fan shaft and forced out a horizontal duct to blast the grain dropping from the hopper into the air stream. By using the appropriate screens, sieves and baffles, the chaff, straw and weed seeds can be separated from the grain. This machine would be very suitable for a small community or cooperative.

A fanning mill is similar to the refined winnowing fan except it is equipped with a series of interchangeable vibrating screens and sieves to clean and grade a variety of grains into different sizes and weights. The air blast and screens remove immature seeds, weed-seeds, dirt, chaff and dust to produce very clean seed. A modern mill equipped with ball-bearings, operates at 200 to 300 rpm., and weighs between 70 and 200 kgs. Research stations, universities and large commercial farms use fanning mills.

b) Processing and Grinding Throughout Equatorial Africa, grain is pounded to pulverize it into flour by women who often work in teams.

The mortar is usually hewn out of a section of tree trunk and the pestle made from a heavy slender pole 200 to 250 cm. long. The mortar bowl varies from 20 to 30 cm. deep and 15 to 25 cm. in diameter. The crushed grain is shaken in a flat basket to bring the coarse grains on top and to one side, whence they are removed for further pounding. Two to four women customarily work together rhythmically to pound the grain in one mortar. This community activity is frequently seen in West Africa. (Figure 3.41.)

A small hand grinder made in Kenya and illustrated in Figure 3.42, was designed to replace the traditional mortar and pestle. It is much faster than hand pounding and the manufacturer states the mill can grind any small grain into grist of desired fineness by using interchangeable screens.

Figure 3.41 Women cooperatively pounding sorghum and millet in a village in the Casamance region in southern Senegal Such operations could be easily mechanized if desirable. Even though simple treadle mortars are available, they may not be acceptable in communities where such work is an important part of the social and cultural life. (AFR-325)

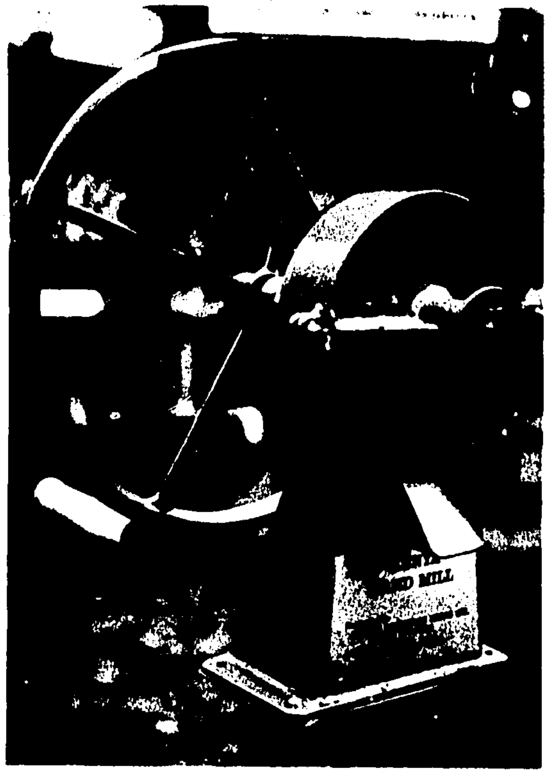

Figure 3.42 Improved hand-powered mechanical grinder made in Kenya
Compared to the traditional mortar and pestle used for grinding maize and small grains, this small machine is more efficient. Hours of toil can be eliminated to permit the woman to devote more time to raising families, marketing and cooking. It is important that service and repair be available at village level if even such simple machines are to be successfully used. Often it is more difficult to get a part for this type of machine than it is for a tractor. (AFR-410)

c) Pumping The flap-valve pump, designed for low-lift irrigation, consists of a cylinder sealed at the top equipped with a spout and flap valve. The whole pump is raised and lowered into the water source by a handle fitted to the top of the cylinder and pivoted on a suitable fulcrum. NIAE trials showed a continuous stream could be produced by a team of two men.[154]

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[154] National Institute of Agricultural Engineering, A *Simple Flap-Valve Pump*, Note No. 1 (Silsoe, England: NIAE Overseas Liaison Unit, n.d.).

The pump is self-priming and works best with short strokes of 15 to 20 cm. at the rate of about 80 per minute. Maximum lift is about four meters. The pump is designed for local manufacturers and might have a place in developing countries with small irrigation potential.

The hand chain pump, weighing 12 kg. and mounted on a portable platform, can lift water from 3 to 4 meters from a tank, canal, ditch or pond. The chain is enclosed in a pipe and the main chain-wheel rotates on heavy-duty bearings. Water-lifting rubber washers are easily replaceable. At least one Indian manufacturer is producing this model pump but it could be made by small workshops in Africa for supplemental irrigation.

d) Transportation Containers such as baskets, jugs, sacks and bundles are used by most people in eastern Africa to carry heavy loads on their backs. Light loads are carried under the arm and sometimes on the head. Limited use is made of shoulder poles for carrying articles in Chinese fashion. Dirt or very heavy materials sometimes are carried by two men on stretcher-like pole carriers. Liquids are carried in large earthen pots or skin bags.

In western Africa nearly everything is carried on the head, from a single Coke bottle to a 40 kg. load of dirt. For short hauls, produce often is carried in baskets or bags. Steel drums of water (200 liters) are rolled down level hard-surfaced roads by one or more men.

2) Output, Power, Capacity and Labor Required

a) Hand Pounding Grinding grain with the mortar and pestle is very slow. Only a kilogram of grain can be processed in the average-sized mortar; and about one hour's steady pounding is needed to crush grain fine enough for flour to make gruel or porridge.

b) Winnowing or Fanning Mill A modern hand-driven winnower running in ball-bearings at approximately 200 rpm., can clean 200 to 1,200 kg. of grain per hour. Operated by one or two men, it produces a very clean sample suitable for seed. In contrast, the average rate for hand winnowing by shaking a shell-shaped basket is about 45 kg. per hour.

c) Transportation and Handling In all parts of Equatorial Africa the human head or back is a load carrier. Hopfen states that "a man can carry a load up to his own weight over distances of about 50 meters or lift it 10 to 15 meters. For long distances, the load should not exceed one-half of the man's weight . . . and women's loads should not exceed 15 kg."[155]

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[155] Hopfen, *op. cit.*, p. 134.

Rural Ethiopians work much harder, often traveling 5 to 10 km. to market to sell produce, wood or other items. Women in the highlands routinely carry back loads of wood that exceed 35 to 50 kg. Only the more fortunate have donkeys or horses to assist them. Water frequently must be carried long distances; large earthen pots filled in streams or ditches hold from 15 to 20 liters.

d) Pest Control and Storage Bengtsson reports that in central Ethiopia:

> All crops that are grown in this area are more or less affected by pests. In stored grain there are expressed complaints about *nekese* which is the grain weevil . . . According to farmers, the pest causes 'very much' loss but the total loss will not exceed 10-15 percent . . . Presently, there is no real means of control although farmers are trying to avoid too many losses. This is achieved by selling the grain as soon as possible which means a low price for the crops because the traders take advantage of the difficulties of the farmers.
>
> *Sitophilus oryzae* is a common pest of stored grain . . . the larvae is confined to cereal grains. Attack begins before harvest, adults flying to the fields from infested stores. The eggs are laid singly in a cavity in the grain. . . . The infestation continues in store with a new generation about once a month. Records from the literature show that 8 percent of the grain is already damaged at harvest, and after six months' storage the damage is reported to be 30 to 50 percent.[156]

Animal Operations

Even a small animal-powered farmer spends much time in shelling, grinding or pounding grains, pulses, nuts and root crops, plus handling and transporting them from the field to the farmyard and market. He and his family may also spend many hours hauling or lifting water. Where community facilities are available for grinding, the farmer may use them, but the women seem to prefer a mortar and pestle. While processing is primarily done by hand or engine power there are a few examples of animals being used for special processing jobs such as crushing sugar cane, extracting oil from sesame seeds or pumping water. However these are rare exceptions in Equatorial Africa. (Figure 3.43.)

Potentially one of the most important jobs for animals, but one that has not been successfully promoted in most of sub-Saharan Africa, is hauling by carts and wagons. Lack of good roads and the isolation of rural areas from permanent and attractive markets, together with lack of an extensive and

[156] Bengtsson, *op. cit.*, p. 51.

Figure 3.43 Camel-powered sesame seed oil extractor in northern Ethiopia
Very few pieces of animal-powered processing or stationary equipment were seen in Equatorial Africa. Imported capstans and gear drives are too expensive and parts are generally not available in Africa. The exceptional craftman therefore, devises ingenious systems using local materials like this power-turned pestle with an offset weighted arm and built-in lubrication. (AFR-446)

well-trained craft and blacksmith service group are constraints. Furthermore, cities and urban populations are along the humid sea coasts, where the tsetse fly prevents the use of animal power for farming. Without high-incentive cash crops and the need to haul larger quantities for market, the farmer has little capital or desire to change his habits.

During the past quarter century, the rapid take-over by trucks and buses of major transportation tasks in the developing countries has prevented development of a strong artisan group as in Europe and the Middle East. Local craftsmen do not know how to construct or repair farm carts and wheels. The few animal-transport devices in use come largely from discarded or wrecked automobiles and trucks. Modern automobiles in sizeable numbers are new to these countries, and there are barely enough used wheel and axle assemblies to meet the need for low cost hand carts and trailers in the industrialized areas. Consequently, junk prices are very high and few parts reach rural farming areas.

Some local agricultural manufacturing has been established in Senegal, Nigeria, and in East Africa. A few carts have been imported from Europe but, compared to the small cultivators' low incomes, they are very expensive. Where carts have been introduced, the government has had to provide long-term liberal credit. Some carts have been introduced into eastern Africa

but the bulk of the Ethiopian produce still is transported on the backs of people and animals.

The EAAFRO Specialists Committee on Agricultural Machinery reported that "much work has been done in East Africa [on carts] but so far no one seems to have produced one which is completely satisfactory. Ox carts should be locally made . . . wood should be used in their manufacture."[157]

Haynes, in a report on ox-drawn implements, in western Africa, wrote:

> Several attempts have been made to popularize ox carts but the efforts of several N. A.'s [Native Authorities] during the early 1950's were a failure because the imported wheels and axles could not be repaired when, after 2 - 3 years use, the hubs and axles were worn out. The most successful, and cheapest carts have been built by village blacksmiths from old car axles and pick-up bodies but numbers have been limited by the number of wrecked cars available and by the high prices obtained for axles for hand carts in towns.[158]

1) Tools and Practices

a) Transportation For centuries, animal-laden caravans have moved across northern Africa to the coasts of the Red Sea. Originating in Ivory Coast, northern Ghana, Nigeria and elsewhere, the caravans crossed vast areas of desert and hazardous terrain to reach Egypt and northern Ethiopia. Figure 3.44 shows a typical camel caravan heading west from northwest Ethiopia. Camels can carry a total of two quintals of grain, one bag of 100 kg. on each side.

Donkeys are the most used beast of burden and can be seen carrying anything treasured by man. Water obtained from rivers, streams, lakes and pools is often hauled long distances; Figure 3.45 shows a donkey with a canvas water-bag holding 80 kg. Other common loads are straw, bags of grain, firewood, branches and household items. (Figure 3.46.) Horses also are used in the highland areas for packing, but more often are ridden.

Mules, considered animals of high prestige by many Ethiopians, are reserved for riding. They are used rarely to carry loads and are seldom worked in the field. In Senegal, Gambia and Ivory Coast, donkeys and horses are used occasionally for pack transport, but carts are being adopted which will make the use of donkeys and horses more efficient. In the lower elevations of Ghana and Nigeria, most loads are carried on the heads of people.

Transport by sled-like devices is common in temperate countries over smooth ground. Crude sleds are also used in high altitude agricultural areas.

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[157] *Minutes of the Meeting of Specialists Committee on Agricultural Machinery, Held at Tenguru, Arusha, Tanzania*, p. 17.

[158] Haynes, *Ox-drawn Implements*, *Section III, Appendix*, p. 1.

Figure 3.44 A camel caravan moving south across the Setit-Humera plains in northwest Ethiopia in late March with loads of inexpensive grain sorghum 1968 prices dropped 50 percent from 1967's good year of $20 to $22/quintal at Asmara. Prices have apparently been affected by four factors (1) a bumper crop in Sudan, (2) closing of the Suez Canal and loss of inexpensive transport to southern Europe, (3) lack of adequate grain storage in northern Ethiopia, and (4) some price manipulation on the part of grain buyers and money lenders. (AFR-155)

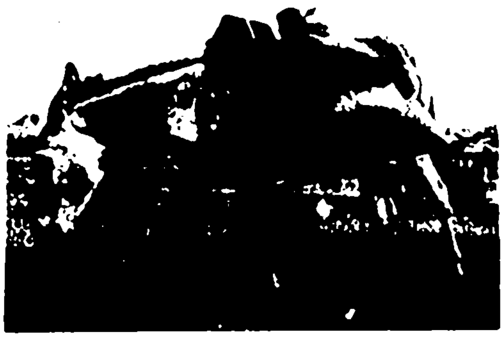

Figure 3.45 Donkey hauling river water in canvas bag in northwest Ethiopia Water for human drinking and cooking and livestock watering is one of the limiting factors preventing or slowing down agricultural development in many areas of Equatorial Africa. Outside the desert areas there is generally enough water but it is not available the year round. The distinct wet and dry seasons without adequate year-round storage or developed underground water sources limit agricultural production to one crop a year. Water shortages also prevent keeping domestic livestock and the expansion of an income-producing livestock industry. (AFR-551)

Figure 3.46 Donkeys transporting straw for building blocks in central Ethiopia One of the most versatile beasts of burden, the sure-footed donkey is excellently suited to travel cross country, and in hilly and mountainous terrain. Owners and handlers exhibit great skill in tieing on and balancing large loads such as seen here in Addis Ababa. However, much larger loads could be pulled on wheeled vehicles.

Figure 3.47 Ox-drawn sled; Chilalo Awraja, Ethiopia The empty sled shows a type of construction using local materials. It is very practical and low cost but its use is limited to farm fields. (AFR-61)

Figure 3.47 shows one type used in Ethiopia. This simple sled is easy to use for hauling bulky loads of grass, vegetation or straw over short distances. It is a laborious job to tie and balance a smaller load on an animal's back. Where adequate methods of yoking and harnessing animals are available, *much more use could be made of sleds as an inexpensive and practical substitute for wheeled vehicles.*

With the wheel, man or harnessed draft-animals can move far heavier loads than by back-carrying or on sleds. The capacity of wheeled transportation is determined more by the ground surface and type of wheels than by the weight of the load.

> If wheels with iron rims are used on even, hard-surfaced roads it amounts to about one to four percent of the total weight of the load and its vehicle; on level, stubble fields it is 10 to 15 percent; and on level, soft fields it is as high as 20 to 40 percent of the weight. With pneumatic wheels, still greater loads can be transported.[159]

The rolling resistance is less with large wheels than with smaller diameters, particularly on uneven ground. Wheel rims can be comparatively narrow on hard surfaces but must be wide on soft ground.

The simplest form of wheeled vehicle, barrows, are generally used for short distance hauling and on narrow paths. A mistake is often made in using too small a wheel, a long body and a high center of gravity all of which make the barrow hard to push, heavy at the handle and difficult to balance and keep upright. The box should be placed between, and not upon, the frame shafts with the gravity point near the ground. The weight on the handles should not exceed 20 kg. Wheelbarrows or bicycle carts could be made easily in developing countries by average craftsmen if they were trained and a suitable source of wheels and axles were available, as indicated by the work of Schneider, Haynes and others in northern Nigeria.

For use on rough uneven ground, carts should have large-diameter wheels. Farm carts vary in size, configuration, and weight depending upon the animal power and land surface. Carts represent the most universally used wheeled vehicles in agriculture, and,except in Equatorial Africa, are the most common tool possessed by animal-powered farmers.

Carts will not become common in Africa until they can be manufactured by local artisans at reasonable cost. Mali and Madagascar have made the greatest impact on cart introduction of any Equatorial African country, with 50,000 and 40,000 respectively in use. (Table III. 8.) The production figures of donkey and horse carts by SISCOMA, while small, show a steady increase in demand since introduction in 1963/64. (Table III. 5.) The production of ox carts, however, has faltered.

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[159] Hopfen, *op. cit.*, pp. 134-36.

A donkey-drawn cart, made by SISCOMA and designed for 400 kg., is fitted with straight double shafts and life-time lubricated Timken roller-bearing automobile-type wheels and tires. The wheel assemblies are purchased from a French company, and with second-grade 5:60 x 13 tires (new car rejects), they cost about $23.00 per pair. The axles are 35 mm. square stock and support the body one meter above the ground on V-frames. The platform, surrounded by a heavy frame 160 cm. long by 12 cm. wide, has brackets for side-racks. The net weight of the cart is 108 kg. and the export price quoted to Nigeria was about $100.00. Parts for the wheels are available from Renault 4 garages, which facilitates service in most African countries. Sales have risen from 280 units in 1965 to 1,480 in 1966, and 2,430 in 1967. (Figure 3.48.)

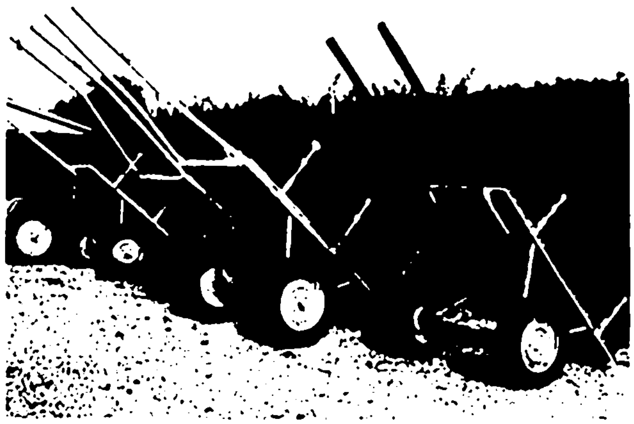

Figure 3.48 Various types of animal carts in Senegal Tongues are adapted for a single horse or donkey (foreground) and a pair of horses or oxen (background). These carts have been made by SISCOMA the past 6 years with gradually increasing sales. Their relatively high price has limited their acceptance and popularity. (AFR-301)

The standard horse-drawn cart and ox cart made by SISCOMA and designed for loads of 1000 kg., is fitted with larger-sized wheels tires, French 165 x 380. The empty cart weighs 190 kg. with a platform 2 m. long by 1.15 meters wide. It can be equipped with either a double (50 mm.) or a single pole (70 mm.) for one or two animals, respectively. The platform is surrounded by a heavy steel frame to which are welded three stake pockets on each side for racks. Prices quoted to Nigeria were about $126.00 for either cart. (Figure 3.48.)

Samaru ox carts, designed by Haynes, consist of a pressed-steel cart frame with pneumatic tires and replaceable hubs. Each wheel is equipped with Oilite, flanged bushings and the hub is dished, so that reversing the wheels would change the tread from 152 to 183 cm., or fit wheels for very soft conditions. Square axles were bolted, rather than welded to the frame so they could be turned 90 degrees when one face became worn to provide four wearing surfaces. Another design used stub axles fitted into a 5 cm. rectangular hollow steel section. The reversible axles had two machined ends and could be turned, to give eight wearing faces.

The Agricultural Engineers Ltd. factory in Zaria, Nigeria is making a simple ox cart patterned after a design developed by Schneider at Ahmadu Bello University.[160] It has a light steel frame 130 x 200 cm. with stub axles welded underneath. The steel tongue is hinged at the axle and fastened with a spring-held pin at the box front so the body can be tilted for dumping. (Figure 3.49.)

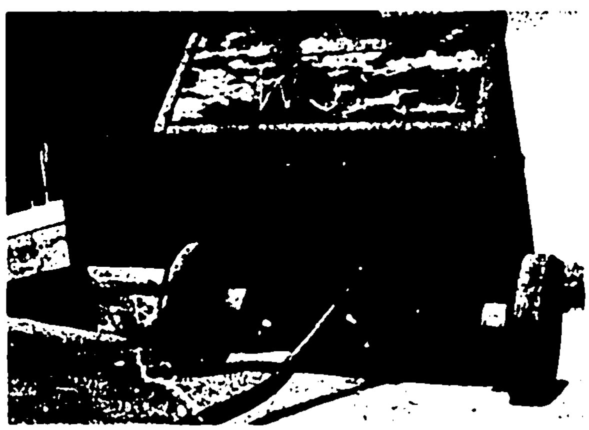

Figure 3.49 Agricultural Engineers Ltd. light-weight ox cart made in northern Nigeria. The angle-iron frame appears to be light for rough farm use. The wheels, axles and bearings were purchased abroad and the tires are used auto and truck casings. (AFR-519)

The floor and sides are made of local lumber but the wheels, axles and roller-bearings are purchased abroad for $22.40 to $25.20 a pair delivered to Samaru. The factory said a major supply problem is lack of good used tires. They

[160] Robert Schneider, Agricultural Engineer, Kansas State Contract Team, Ahmadu Bello University, Samaru, Northern Nigeria, Personal Communication, April, 1967.

also are experimenting with sleeve-bushings mounted in a welded hub to take wheels and tires the same size as the Peugeot pick-up common in Nigeria. The selling price of the current ox cart is $112.00.

SISCOMA has made a few low-profile heavy-duty ox carts that are considerably heavier and more expensive with a designed capacity of two tons. At Bambey Centre for Agronomic Research the research engineer said it was well built, but prices and detailed specifications are not known. It has heavy-duty axles, wheels and bearings set in wells on the edge of the platform. The low body, 60 cm. above ground, is equipped with both end- and side-racks. The unit appears well-balanced but needs two strong oxen to pull a full load. (Figure 3.50.)

The Singida steel-wheel ox cart is made with a live axle and wooden bearing-blocks in southern Tanzania. When tested by TAMTU, it was reported satisfactory for local hauling. The cart sold for about $60.00. If suitable wheels and axles could be obtained, the cart could be mass produced. (Figure 3.51.)

Shambaugh in northeast Nigeria used a different approach to cart fabrication by taking the rear gear assembly of a standard U.S. four-wheel farm wagon to make a heavy-duty two-wheel cart. His goal was to produce a cart at a cost of about $55.00 to $85.00 which would carry 1,356 kgs. at speeds up to 32 kph. The cost, less tires, was about $31.00 FOB, the U.S. factory. The fabrication is very simple, requiring only the addition of a 3.67 meter section of reinforced pipe for the tongue and a locally-built wooden body. The chassis is extremely sturdy for an ox cart, and with a short tongue, it can be used behind a tractor. (Figure 3.52.) *The Bornu ox cart is one of the best ideas for a durable animal cart which could be supplied from the United States at a reasonable price.*[161]

The CADU project has looked for a simple way to put the small Ethiopian farmer on wheels. The best way appears to be to import suitable automotive-type wheels, tires and axles from overseas and build bodies and frames locally pending establishment of a local factory. Ten wooden- and steel-wheel carts have been built out of old machinery and transport wheels, and have been loaned to farmers for tests. (Figure 3.53.)

Four wheels provide much greater stability and balance, without vertical pressure on the animal, or danger of the load tipping. There are two disadvantages for Africa: first, two sets of wheel-and axle-assemblies will

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[161] Shambaugh, *Summary of Developments in Progressive Mechanization for the Hand and Mixed Farmers in the Savannah Zone of Northern Nigeria*, p. 18.

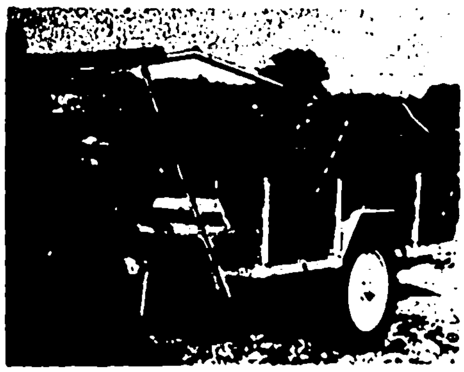

Figure 3.50 Improved heavy-duty ox-wagon with racks Two oxen can haul 1400 kgs. with this unit manufactured by SISCOMA for the first time in 1968. While quite expensive it represents a sound design with easily rolled pneumatic tires and low platform height. (AFR-302)

Figure 3.51 Singida (Tanzania) wood-bearing steel-wheel ox cart Originally made by a missionary group in south central Tanzania, this simple but rugged cart performed well and exhibited good durability when tested by the Tanzanian Agricultural Machinery Testing Unit. Unless a local source for inexpensive steel wheels is available it will generally be less expensive, and far superior, to use standard automotive roller bearings, wheels with pneumatic tires. For small numbers of carts steel wheels can be used, but for any mass production of improved carts and wagons, it will be more economical and practical to use the modern mass-produced wheel assembly. (AFR-540)

Figure 3.52 Shambaugh's Bornu heavy-duty ox cart Made from the rear half of a U.S. built farm wagon, this two-wheel ox cart is one of the best solutions to the dilemma of how to develop a low cost but durable cart. The reach is simply replaced with a pipe to form the tongue and a platform and body are built locally. If available, used tires can be furnished locally but they are in critical supply in most developing countries. (Photo courtesy of T.J. Shambaugh, Jr., USAID/ Nigeria, Industrial Development Center, Zaria, Northern Nigeria, 1969)

Figure 3.53 Chilalo Agricultural Development Unit ox cart This inexpensive cart was fabricated from the transport unit of an old combine or binder. It has limited possibilities because only a few junk machines are available and the repair and replacement of worn bearings will be difficult. The steel wheels also limit its use to gravel and dirt roads and to (Photo courtesy of B. Karlsson, CADU/SIDA, Asella, Ethiopia, April, 1969) (AFR-469)

almost double the cost to the farmer; and second, strong suitable animals and harnesses are scarce. Farm wagons are available in developed countries in practically any size desired, but few are found in Equatorial Africa. An advantage of the Bornu ox cart is it can be converted to a four-wheel wagon later by simply adding the front half of the running gear plus a reach to join them.

Automobiles have influenced development of farm wagons by providing a fixed front axle with steerable front wheels on stub axles. This steerage gives great stability when turning corners since it allows a short turning radius, and the hitch pole or shafts do not transmit road shocks to the draft animals. The low-loading platform of these wagons is also a great advantage.

Animals can be effectively utilized for short-haul earth moving operations using scoops or blades. Even though they are slow, large amounts can be moved and packed by animal teams. In a country like Ethiopia it is economically desirable to use animals in outer regions having adequate animal power, but lacking a well developed or adequately supported engine-powered agriculture and transportation network. One contractor has 50 ox teams in the Awash valley building irrigation dams and levees at rates lower than offered by tractor equipped contractors. (Figure 3.54.)

Figure 3.54 Ox-drawn blade scrapers building levees in eastern Ethiopia
Even where tractors and equipment are available it is sometimes less expensive to use animal draft for selected operations. Tendaho Plantations found that the contractor with up to 50 teams of oxen could construct both small and large earth levees more economically than could be done with crawler tractors. The levees are used to control flood irrigation waters and to improve irrigation efficiency and water spreading. The oxen do an excellent job of packing particularly when building up larger mounds. (AFR-473)

b) <u>Processing and Water Pumping</u> A horse or camel-driven mill built by a Portuguese firm was seen in Senegal. While designed for use with a reciprocating water-pump, it might prove useful as a power source for high-capacity decorticators. Haynes says, "Its main advantage over homemade mills is in its clever use of castings which would have to be imported from Casablanca."[162] The power train is driven by a revolving cap rotated by two long arms about 4.6 meters in length. The animal-hitch-point can be moved in to increase speed or out to increase power.

A simple but effective mortar-and-pestle camel-powered mill was observed in northwest Ethiopia. To extract oil from seseme seed, the pestle is rotated by a heavily-weighted offset arm and beam. One batch of seed is processed at a time with the oil rising to the top and furnishing excellent lubrication. At the end of each batch the seed cake was packed against the edges of the mortar and had to be broken out before new seed could be added. (Figure 3.43.)

The Persian water wheel is widely used for raising water from shallow wells in India and the Far East and could be used in Equatorial Africa. It is powered by oxen and driven from a shaft by peg-gearing. An endless chain of buckets are mounted on a large diameter wheel at the top of the well. As the wheel rotates, the buckets dip into the water at the bottom of the well and lift it to the top into an irrigation canal. Constantinesco says a "disadvantage of the Persian wheel is the large diameter of the wheel which necessitates a large diameter well to accomodate it, so that the whole outfit is rather expensive."[163]

The Chain pump, the animal-powered device inspired by the Persian wheel, eliminates the need for a large well. Basically, it is a link chain driven by a small diameter wheel and passed through a pipe from the water to the top of the well. At intervals along the chain are fastened steel and rubber washers which push water up the pipe and discharge it into an irrigation channel. Constantinesco says, "The rubber washers are more efficient and although they wear out they can be easily and cheaply replaced by cutting them out of old lorry and tractor inner-tubes."[164] Price and use in Africa are unknown but this pump could be used for small-scale irrigation in animal-powered areas of Equatorial Africa if its import price were attractive or it could be locally manufactured.

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[162] Haynes, *Report on a Visit to Senegal*, p. 7.

[163] Constantinesco, *op. cit.*, p. 10.

[164] *Ibid.*, p. 11.

2) Output, Power and Capacity Required

a) Farm Carts and Wagons Single-animal carts can haul 400 to 900 kg. if the load is properly positioned. Two-animal carts in Equatorial Africa are usually pulled by oxen and can haul 900 to 1300 kg. Two-animal farm wagons pulled by either oxen or horses are rated up to 2700 kg. under good conditions.

b) Processing Equipment Capacities vary greatly, depending on kind and number of animals, length of rotating arm, evenness of load, shock-loading and hours of operation. Although no detailed data were obtained on outputs or capacities of animal-powered units, most are operated by one or two animals. The camel-powered sesame mill is operated six hours a day and produces an average of 60 liters per day.

c) Water Pump Cossul and Co. Ltd., Kanpur, India make an animal-driven chain pump. It has a discharge of 1140 to 1500 liters per hour and is usable for depths up to 13 meters. It can be installed in a well as small as one meter in diameter. The gear ratio is 1:5 and it uses two oxen for power.

3) Time and Labor Required

Hauling times depend upon the animal, its health, type of cart, cart wheels and condition, load, road-type and condition, topography and weather. Most animal-carting is short distance, being primarily farm to local market. Since carts have been used very little in Equatorial Africa, little information is obtainable on their economic use.

Small donkeys carry large loads for their size. It is not uncommon to see a 150 kg. donkey carrying a 100 kg. sack of grain in Ethiopia, obviously under considerable strain. With an easy-rolling cart on a firm level surface, this same donkey could haul four to five times that much. However, where there are very poor roads, or only narrow winding tracks and trails with steep slopes, there is no better transport at present in the rural areas than the sure-footed animal.

Little information is available on animal processing equipment and quantitative information is not available. A few mortar and pestle and capstan-operated mills and water pumps seem to be the only stationary use now being made of animal power; and no cases were investigated in Equatorial Africa.

4) Skill and Management Required

Loading any kind of two-wheeled cart requires skill and judgment to maintain proper balance without overloading the animal or risking the danger

of tipping backwards on hills.

The proper lubrication of sealed and anti-friction bearings is a critical problem with carts. Factory lubricated, prepacked or so called "lifetime" bearings still need attention. Seals wear out due to intrusion of mud, dust, fine sand and water.

Bearings must be repacked when they begin to show signs of looseness, leaking grease, or after exposure to extreme conditions of moisture and dirt for prolonged periods. Since the average small farmer is unfamiliar with such problems he needs advise and help by qualified technical people.

Preventive maintenance for wheeled vehicles means timely lubrication, adjustment for bearing wear, replacement of bushings or bearings before the hub and/or axle are damaged, rotation of axles where possible, keeping lug nuts tight, keeping tires properly inflated and avoiding tire cuts and damage.

Over oading is a danger, although with one or two small animals a safety factor exists, since the maximum load is limited. Nevertheless, wheels become deformed, tongues bend, axle brackets give, or frames spring, allowing loads to shift and increasing breakage and wear-rate on the body or other parts.

5) Costs Involved

Of all the tools owned by animal farmers, the cart receives the most year around use. To the casual observer, the upkeep of a farm cart seems a simple thing with relatively minor expenses. However, the following costs on ownership (Table III. 18), prepared by Haynes show that its use and proper care involve considerable expense for the farmer. The estimates were based on an original cost of $120.00 for the cart, not including road license fees.[165] Haynes explains:

> Working lives were assessed pessimistically but it was assumed that the factory would buy back old axles, hubs, etc., for repair at realistic scrap prices. The capital cost was included by assuming the cart was purchased with a loan repayable over five years with interest at 5% on the decreasing balance. With bushings replaced every second year, a new set of hubs every fourth year and new axles and tires every six years, the ownership costs were:

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[165] Haynes, *Interim Report on Test on Ox-drawn Implements as Groundnut Lifters*, p. 73.

TABLE III. 18 COST OF OWNING AND MAINTAINING A PNEUMATIC-TIRED TWO-WHEELED OX CART: NORTHERN NIGERIA 1965

Year	Parts and Labor	Annual Cost
		dollars
First year	none	29.15
Second year	New bushings	29.28
Third year	none	26.64
Fourth year	New hubs and bushings	26.48
Fifth year	none	23.54
Sixth year	New axles and tires and bushings	49.49[a]
Seventh year	none	-
Eighth year	New hubs and bushings	18.90
Ninth year	none	-
Tenth year	New bushings	10.85
	Residual scrap value	21.00

[a]If steel wheels were used in place of pneumatic tires, the cost of the sixth year would be $24.10, but the bearings would wear faster requiring earlier replacement.

No cost records were obtained on the operation of animal-processing equipment either for ownership or operation in Equatorial Africa.

Engine-powered Implements and Attachments

Of the many engine-powered or tractor-pulled and -driven implements and units of equipment now in common use or potentially usable in Equatorial Africa an evaluation is useful of those with the greatest application potential or a particular relevance to agriculture in the tropics. *There is a place for engine-powered agriculture in developing nations just as there is an obvious need for improved hand- and animal-powered systems.*

Engine-powered implements can handle all operations in tillage, planting, weeding, harvesting, processing and transportation. Many machines are multipurpose or have attachments which enable them to perform simultaneously more than one of these operations, in contrast to hand and animal tools and implements which are essentially single-purpose.

There are many good tractors and implements developed and used in more advanced countries that can be operated in Equatorial Africa with little modification when they are: selected to perform under prevailing climatic and operating conditions; realistically applied to a system of farming; suitably designed for the crop; chosen to fulfill functional requirements; supported by a dealer and service organizations; and operated by well-trained farmers or employees.

In introducing more sophisticated power and implement systems the following should be guarded against:

1. Using tractors and associated tools on land which has not been properly cleared.

2. Sending tractors and implements into the field without adequate supervision and essential supplies.

3. Selecting the most elaborate tractor model with many power options such as steering and shifting and draft control for use many miles from the nearest service facilities.

4. Turning expensive tractors and implements over to improperly trained operators and then expecting satisfactory performance.

5. Supplying only plows or harrows with tractors when additional implements are needed to effectively utilize the tractors and produce the crop.

6. Trying to do good work with plows or implements which are incomplete, damaged or improperly adjusted.

7. Selecting wheel or crawler tractors with closed cabs that are uncomfortable for the driver in the tropical sun.

8. Bringing in mechanical harvesters before there are suitable driers, mills or gins to process the mechanically-picked crops.

It is important that officials and farmers in developing economies have an accurate idea of the *true costs* of owning and operating expensive machinery. In general, *at the present stage of development, education level, dealer organization, accrued experience and expertise with machinery; estimates of length of service-life of a tractor or implement used in costings must be greatly reduced, and the estimated cost of repairs and maintenance considerably increased in order to determine the cost of machinery use in Equatorial Africa.* Only on carefully-supervised commercial plantations and schemes, frequently managed by expatriates, can cost be held down to economical levels.

Table III. 19 suggests practical values for calculating costs of using machinery under climatic conditions found in Equatorial Africa. The low productive use, high repair costs and early mechanical failures in tropical regions indicate that these costs of using machinery are valid in the countries considered by the Study; a similar guide is given by the Asian Productivity Organization for use by its members in southeast Asia.[166]

Approximate draft requirements and operational speeds for more advanced engine-powered tools and implements are given in Table III. 20. Power requirements for any given tool will vary greatly, of course, with type of soil, topography, moisture content, vegetation, speed, condition and adjustment of the implement, depth and angle of cut, and operator's skill. In

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[166] *Record of Expert Group Meeting on Agricultural Mechanization*, Vol. I (Tokyo: Asian Productivity Organization, June, 1968), p. 64.

TABLE III. 19 PERCENTAGE VALUES FOR ESTIMATING ANNUAL OVERHEAD COSTS OF STANDARD-SIZED MACHINERY, ADAPTED TO DEVELOPING COUNTRIES OF EQUATORIAL AFRICA

Machine	Estimated Life	Straight line Depreciation	Overhead Charges as Percentage of Original Cost[a] Interest[b]	TIHL[c]	Repairs	Annual Total
	years	percent	%	%	%	%
Tractor, crawler	7	14.3	4.0	4.0	12.0	34.3
Tractor, wheel	6	16.6	4.0	4.0	10.0	34.6
Plow, disk or moldboard	7	14.3	4.0	4.0	10.0	32.3
Harrow, disk	6	16.6	4.0	4.0	10.0	34.6
Harrow, tooth	8	12.5	4.0	4.0	8.0	28.5
Tiller, rotary	6	16.6	4.0	4.0	10.0	34.6
Leveler, small	8	12.5	4.0	4.0	8.0	28.5
Planters, seed	10	10.0	4.0	4.0	5.0	23.0
Drills, w/o fertilizer	10	10.0	4.0	4.0	5.0	23.0
Sprayer, PTO or engine	8	12.5	4.0	4.0	8.0	28.5
Mower, sickle or rotary	7	14.3	4.0	4.0	10.0	32.3
Combine, pull or SP	6	16.6	4.0	4.0	10.0	34.6
Rice huller	8	12.5	4.0	4.0	5.0	25.5
Seed cleaner	10	10.0	4.0	4.0	3.0	21.0
Wagon, 2 or 4-wheel	8	16.6	4.0	4.0	5.0	29.6
Pumps, irrigation	7	14.3	4.0	4.0	4.0	26.3

[a]Does not include drivers' wages, routine maintenance service charges, fuel and lubrication costs, and high usage supplies like plow points and twine.

[b]Interest is based on average of one-half value throughout machine life, using only official rates for borrowing from government agencies.

[c]Taxes, Insurance, Housing and license fees.

TABLE III. 20 APPROXIMATE DRAFT REQUIREMENTS AND SPEEDS OF OPERATION FOR FARM MACHINES IN EQUATORIAL AFRICA[a]

Machine	Typical Power Requirements per area or cm. of width	Speed km./hr.
Plow, indigenous	0.14-0.70 kg./cm.^{2}	1.61 - 2.42
moldboard	0.21-1.12 kg./cm.^{2}	2.42 - 4.84
disk	0.21-1.00 kg./cm.^{2}	2.42 - 5.65
Disk harrow, single action	0.45-1.50 kg./cm.	1.61 - 4.03
double action	1.20-2.70 kg./cm.	1.61 - 4.03
Rotary tiller	0.70-3.50 kg./cm.	0.80 - 2.42
Harrow, spike or peg	1.80-2.70 kg./peg	1.61 - 4.84
spring tine	10 - 25 kg./tine	1.61 - 4.84
Roller or puddler	0.15-0.90 kg./cm.	0.80 - 4.03
Leveler, float	0.30-0.70 kg./cm.	1.61 - 4.84
Row-crop planter	30 - 70 kg./row	1.61 - 4.84
Grain drill	6 - 22 kg./row	1.61 - 4.84
Transplanter	10 - 20 kg./row	0.80 - 2.42
Combine, self-propelled	0.48-2.25 kg./cm.	1.61 - 4.84
Mower, tractor	0.12-0.37 kg./cm.	1.61 - 4.84
Grain binder	0.97-2.25 kg./cm.	1.61 - 4.03

[a]*Record of Expert Group Meeting on Agricultural Mechanization*, Table 1, p. 61 and Chilalo Agricultural Development Unit, *Preliminary Results of Farm Implement Research* Implement Research Station Publication No. 2 (mimeographed) (Addis Ababa: Swedish International Development Agency, June, 1969).

areas with distinct wet and dry conditions, lateritic soils become very hard as they dry out, *e.g.*, northern Nigeria and Ghana.

Some typical field capacities per 30 cm. of width are indicated in Table III. 21 for various field machines. Capacity depends upon width, speed and field efficiency, or percent of time a machine is actually working. Blockages, short fields, obstructions, small and irregular areas, and poorly defined boundaries slow down operations.

TABLE III. 21 TYPICAL EFFECTIVE FIELD CAPACITIES OF ENGINE-POWERED FARM MACHINERY IN TROPICAL REGIONS[a]

Operation and Unit Width	Capacity	Average
	ha./hr.	hrs./ha.
Plowing, 15.2 cm.	0.02 - 0.04	40
35.5 cm.	0.05 - 0.14	10
Disking, per 30 cm.	0.03 - 0.10	15
Rotary tiller, per 30 cm.	0.02 - 0.06	27
Harrow, per 30 cm.	0.03 - 0.13	12
Roller or puddler, per 30 cm.	0.02 - 0.10	18
Leveler, float, per 30 cm.	0.03 - 0.12	15
Row-crop planter, per 30 cm.	0.02 - 0.10	17
Grain drill, per 30 cm.	0.03 - 0.11	15
Transplanter, per 30 cm.	0.01 - 0.04	40
Mower, per 30 cm.	0.02 - 0.12	14
Combine, per 30 cm.	0.02 - 0.11	15

[a]Adapted from *Record of Expert Group Meetings on Agricultural Mechanization*, Vol. I, Tables 3 and 4 (Tokyo: Asian Productivity Organization, December, 1967), p. 62.

Technical Factors and Constraints

Small Engine-powered Machinery

1) Small Two-wheel Tractors

a) Titan Merry Tiller This walking-tractor designed primarily for rotary cultivation is manufactured by Wolseley Engineering Co., Witton, Birmingham, England. Power is transmitted from the Clinton air-cooled engine to the rotor shaft through a V-belt and chain drive. When used as a rotary cultivator, forward propulsion is achieved by the power-driven rotor. A tine fitted behind the rotor brakes the forward motion and controls the depth of work. A throttle and a V-belt clutch release control the machine. Different combinations of rotors may be used to adjust the working width. Attachments are available for plowing, weeding, ridging, mowing, light hauling and stationary work. This tractor was officially tested by the Kenya Agricultural Machinery Unit, Department of Agriculture, and a test report issued:[167]

[167]S. W. Cooper, "Test Report on a Walking Tractor", *Kenya Farmer*, Reprint, June, 1966, p. 1.

> The machine was used for a total of 100 hours in 14 relatively tough conditions which consisted mainly of breaking Kikuyu and Rhodes grass pastures, stubbles, seed-bed preparation, weed control and inter-row weeding. Depth measurements in all conditions were taken to the level of the soil after cultivation to avoid confusion in the case of soils previously loosened. On completion of the test the machine was dismantled and examined . . . The ground-engaging parts showed little sign of wear; the chain-drive sprockets and bearings were in good condition; and there were no oil leaks. There was no undue wear in the engine . . . The Titan Merry Tiller . . . was capable of producing satisfactory results in most conditions when the engine developed ample power to meet requirements. No serious mechanical break-downs occurred and no excessive wear or distortion was apparent at the end of the test.

b) Landmaster 150 This 6.0 hp. two-speed primary transmission, 80 kg. single-axle walking tractor has been tested in southeast Asia, the Philippines and Kenya. Manufactured by Landmaster Ltd., Hucknall, Nottingham, England, it is now being introduced into eastern and western Africa by the Singer Sewing Machine Company. Like the Titan, it is basically a rotor-drive cultivating unit but usable for a variety of other jobs. A complete set of attachments includes a rice thresher, irrigation pump, trailer, seeder, rotary and sickle bar-mowers. (Figure 3.55.)

Figure 3.55 Landmaster 150 (British) two-wheel walking tractor with irrigation pump This 6 hp. tractor can perform many tasks although it basically is a rotary cultivator, propelled by the soil working blades. It is also excellent for mowing grass and for puddling rice paddy. (AFR-554)

In the past five years Landmaster sales have increased considerably in Europe; selling about 4,500 tractors annually in England. In 1967 1,500 tractors were sold in the Philippines and during 1968 they expected to sell 350 in East Africa. Farmers around the Meru area in Kenya are using 120 machines. In Ghana Singer had sold 22 machines by April 1969, and have applications through the Agricultural Development Bank and The Tobacco Growers' Association for another 30. The Sugar Growers' Association have three machines. Farmers are using Landmaster 150's in inter-row cultivation for weed control.

In Kenya Singer has 20 shops and men working with the Landmaster. Seven teams of sales and service personnel, all trained in Kenya, can give 24-hour service in any area. On Agricultural Finance Loans Singer provides free parts for one year and free service for life. They are using the JLO two-cycle engine because it can be used on slopes without danger of loss of lubrication. On hire-purchase plans, a service man makes monthly checks on the machine and operator and corrects deficiencies. Singer claims they can train a man to use the Landmaster in two hours. The only trouble with the engine has been operational carelessness and lack of maintenance. About 75 percent of the purchasers of Landmaster tractors are people with other jobs, such as civil servants, school teachers and agricultural workers.

The provisional report on the Landmaster from the Ghana Ministry of Agriculture is good. One unanticipated problem has been the attitude of the farmers to "wait and see" if the company stays in business to give spare parts and repair service. The discontinuation of some products after only a year of sales has created suspicion of new products among farm customers.[168]

Singer uses a demonstration for on-the-farm visits with a complete set of equipment and service facilities. They extend six-months' credit to good risk customers. There is a difference in quoted prices between Africa and the Philippines. A suggested dry-farming set consists of the basic L-150 power unit, a moldboard plow, one pair of 18 cm. wide steel wheels, one pair of 500 x 12 rubber-tired wheels with ratchet hubs, and wheel weights, and a front counterweight and bracket. In the Philippines this sells for $988.00 cash or $1,215.00 on credit with 35 months to pay; in Kenya this set was quoted at $790.00 cash.

A rotary cultivating-set consisting of the basic L-150 machine, a rotor-axle, an 84-cm. curved-blade rotor set, a wheel-support frame, front weight and bracket sells for $748.00 cash price in the Philippines or for

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[168] D. McKenzie, formerly Manager, Singer Sewing Machine Co., Accra, Ghana, Personal Communication, July, 1968.

$850.00 list price with 26 months to pay. In Kenya the cash price was given as $576.00. In Ghana the basic Landmaster tractor with 91-cm. rotary tiller and the JLO 6.5 hp. engine sells for $539.00 cash. The irrigation pump with 7.6 meter suction hose is priced at $164.00 and the two-wheel trailer at $100.00. Prices may be more favorable in Equatorial Africa because of lower freight costs.

c) Landmaster 150 Attachments The single-furrow moldboard plow turns a furrow 23 cm. wide and 10 to 15 cm. deep. Equipped with a large landside, rolling-coulter and replaceable share, it is easily controlled and can do good work in trashy fields because of its high clearance. For dry-land plowing extra weight must be added to the tractor wheels and a counter-weight on the front for effective traction. Weight of plow is 24 kg.

Patterned after the Japanese rice-plows, the slatted moldboard plow is reversible to permit back and forth plowing. A crank controls depth and penetration and special paddy wheels are used normally to help support the tractor in very soft soils and to assist in working up the paddy. Plow weight is 16.5 kg.

For puddling and leveling rice paddies, a pair of 45-cm. wide rotary cage-wheels and a 92 cm. finger harrow or leveling rake are used together. Because the rotor power unit is completely sealed against entry of mud and water, this machine can work partially submerged in rice paddies.

Three different types of blades are supplied to work different soil under varying conditions. *Curved* blades are used for normal cultivation, deep tillage and hard soil conditions; *slasher* blades are used for general purpose and trashy ground; and *pick* tines are designed for very hard, compacted soil or stony ground. One to four pairs of blades may be used to select row-working widths of 33, 27, 33 or 45 cm. Ridging rotors are available to ridge up special crops, to mulch weeds and trash or to mix in fertilizer.

A 92 cm. oscillating sickle-bar mower can be mounted on the front to cut and wind-row crops. It can be used to cut on banks up to a 45° angle.

A front-mounted wheel-supported 61 cm. rotary mower is available for clipping grass and weeds, for pulverizing crops prior to cultivation and for mowing heavy weed growth up to 122 cm. high. With the Landmaster mower, smaller drive-wheels must be used because the large wheels used for plowing and transport propel the tractor too fast for satisfactory cutting.

A two-wheel trailer unit has a 300 to 400 kg. capacity with 4.00 x 8 pneumatic tires. It is equipped with a parking brake for use in emergency stopping.

A Singer-made self-priming irrigation pump with base and stand can be attached to the tractor's front-weight bracket. Capacity is 29,550 liters per hour. A 7.6 meter 5 cm. suction-hose with strainer is used. (Figure 3.55.)

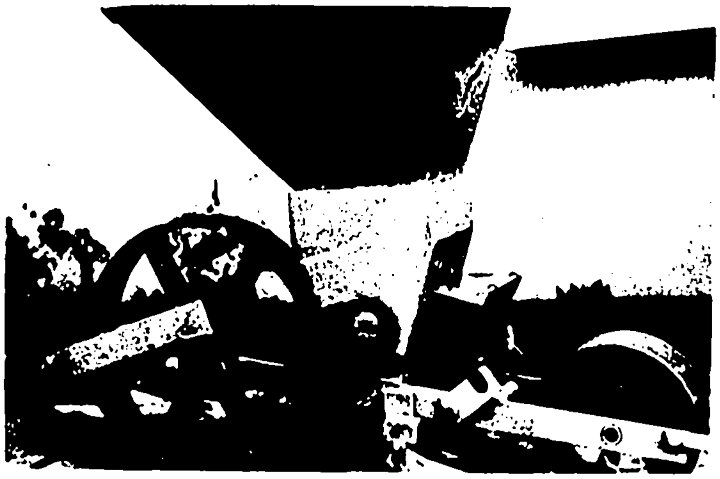

Figure 3.56 Landmaster brush-type all-purpose vegetable and small grain seeder Although designed to go with the Landmaster tractor it could be used with any pulling tractor designed for field work. The brush-type seed-metering device performs well providing the bristles are stiff and bunched together. Planting units can be hooked together in gangs to sow two or more rows. (AFR-550)

A grain thresher, made by Garvie of Scotland to NIAE specifications for paddy threshing, is said to be suitable for wheat, sorghum, mango and guinea corn. The average output for rice is reported as 1,000 to 1,360 kg. per hour. The thresher is attached to the front and left side of the tractor. It, like the irrigation pump and mowers, is driven from the engine pulley at 1,500 rpm.

The power-take-off and flexible drive accessory is used to power other attachments such as a chain saw, drill or grinding wheel.

A brush-type seeder in single- or twin-gang arrangement is available to plant seeds up to pea size. According to Cooper's tests of seeders at KAMU in Kenya, the brush-type agitator seeders are satisfactory provided the bristles are bunched together to give a paddle effect. (Figure 3.56.)

A four-row boom sprayer for the small farmer is manufactured by Leading Engineering Co., Nairobi, Kenya. An axle cam drives a piston pump and the spray tank is mounted on the rear. The sprayer originally was designed for ox farmers but never gained farmer acceptance. For small holders raising rice and cotton crops it should be a useful attachment. (Figure 3.57.)

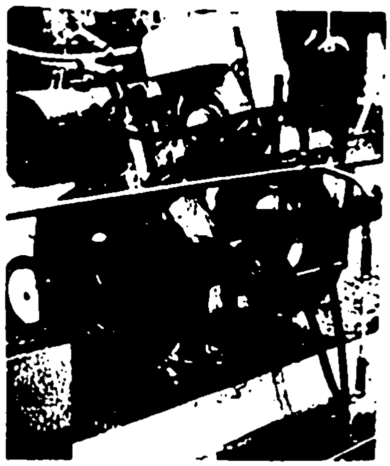

Figure 3.57 Low-volume field sprayer (Kenya) made for Landmaster tractor
This is an example of special purpose equipment made by a local manufacturer (Leading Engineering) and designed to increase the usefulness and productivity of newer agricultural tools. The spray boom shown covers four rows and can be adapted to various crops. The pump is driven off the axle by an eccentric cam and crank arm and the tank is located on the rear. Originally designed to be used with animal-drawn equipment it never found a market. (AFR-549)

d) Agria Farmworker A new German two-wheel tractor, the Agria Farmworker, was seen at the Sunyani, Gnana Agricultural Show. The 4.5 hp. Farmworker is a two-wheel tiller; with the import price of a moldboard plow and trailer, estimated at $500.00. Attachments include a two-way moldboard plow, two-wheel trailer, a 122 cm. sickle mower and a 183 cm. spike-tooth harrow. The single-axle models also come in 6.5 and 12 hp. sizes, and the 4 wheel models in a 10 to 12 hp. riding tractor with a choice of a gas or diesel engine.

e) Toro Tiller The Toro tiller is a gear-drive machine with a 4.5 hp. Briggs and Stratton engine. With rotary blades, the export price

FOB New York is about $98.00 each in lots of 100 machines. These could be imported to Ghana for about $130.00 each.

f) Honda Power-tillers The University at Ife, Ile-Ife, Western Nigeria, has tested several models of the Honda power-tiller for suitability. Stetler reports that three models are available with the 3 1/2 hp. size being the most satisfactory. He reported:[169]

1. The F-25 is a 2 1/2 hp. lightweight model selling for $140. The rotary cultivator and moldboard plow work well in clean soils but are hopeless in soils with roots, stumps and stones.

2. The F-40 is a 3 1/2 hp. model selling for $280 which works well and is fairly simple and easy to service. Stetler believes that if a farmer could increase his maize and yam area from 1.2 to 2.4 hectares without hiring more labor he could probably pay for it in three years. A good farmer should get 1,020 kg. of maize and 3,640 kg. of yams per hectare. (Figure 3.58.) Stetler stated the steel blades on the Honda needed replacement after cultivating about 4 hectares.[170]

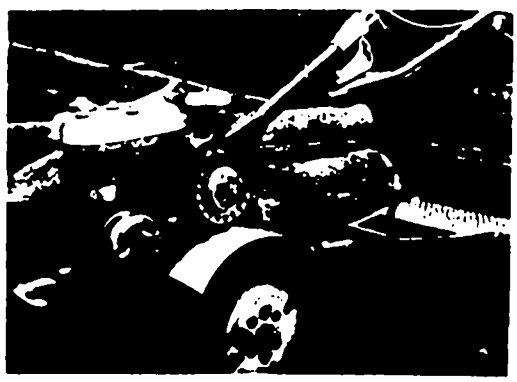

Figure 3.58 Honda F-40 (Japanese) power tiller and trailer This 3.5 hp. tiller is one of the more sophisticated small tractors and power tillers recently test-marketed in Africa. Generally more expensive and complicated than European and American models of similar horsepower, it has not received extensive promotion nor been widely distributed. Asian built machines are not always suited to climatic and soil conditions in Equatorial Africa. The great distance from factories and to major suppliers also places purchasers at a disadvantage for parts and service. (AFR-520)

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[169] Stetler, *op. cit.*

[170] *Ibid.*

3. The F-190 is a 5 hp. model with rotary-blade rotavator. It does the easiest job and works best with wheels to control speed and action of rear-mounted rotavator. However, a "fancy" electric starter and lights, and complicated engine increase its cost and make it difficult for African farmers to service. A farmer with sufficient money to buy a Honda F-40 rotary tiller, probably would go into cocoa or permanent crops giving a higher cash return.

2) Small Four-wheel Utility Tractors

a) Self-helper Tractor, Model G-12 Manufactured by Self-help, Inc., Waverly, Iowa, this small 12 hp. power unit comes closest to big tractor capability for its size (137 cm. wheelbase) and price of any small tractor currently manufactured. It incorporates features not found on most small tractors: simplicity, true ruggedness, large drive-wheels (8.00 x 16 rear tires), provision for extra weight to obtain necessary traction, a power-take-off for stationary work, and a wide range of matched attachments. The standard Kohler gas or kerosene engine features automatic compression release for easy starting which releases the normal high compression past the exhaust valve at cranking speeds. Advantages are that the engine starts with a gentle pull, without kickback, flooding or loss of horsepower.

To make maximum use of power, extra weight is recommended in the form of 45 kg. of fluid in each rear tire, 41 kg. cement weights on each rear wheel and a 45 kg. counterweight bolted under the front axle. With this front weight removed, the unit has 36 cm. clearance under axles for cultivating. Tractor weight, including counterweights but not the operator is 518 kg. Price for the complete basic tractor with 12 hp. gas engine is $542.65 FOB Waverly, Iowa. With a 10 hp. Clinton engine and without the hand-operated emergency brake, it is $507.90 FOB.

The manufacturer says the tractor has been produced for over 25 years and thousands have been sold. For overseas u.. it has a lower first gear for heavy plowing in hard soil, a reinforced frame and axle for greater strength and rigidity and weights for traction. Self-help gives a one-year guarantee if the tractor, engine and parts are defective under normal service. (Figure 3.59.)

Normally the tractor and implements are shipped disassembled to save freight after being assembled at the Iowa shop to be sure all parts fit and are properly adjusted. This provides an opportunity to set up a small assembly plant overseas, to train workers or farmers in basic mechanical principles and to familiarize them with the machine. The price of individual components, disassembled, is shown in Table III. 22.

Figure 3.59 Self Helper (United States) 12-hp. four-wheel tractor with moldboard plow and mower Designed especially with the small cultivator in mind, it is relatively simple with provision for adding considerable weight to take advantage of available power. The tractor pulled this plow in fine-grained soils at high altitude with comparative ease. Many other attachments are available but they all cost considerable money from the viewpoint of the small farmer. (Photo courtesy of R.P. Rooney, USAID, Addis Ababa, Ethiopia, April, 1969) (AFR-545)

TABLE III. 22 DESCRIPTION AND COST BREAK-DOWN OF COMPONENTS OF SELF-HELP FOUR-WHEEL TRACTOR DEVELOPED FOR SMALL FARMERS IN DEVELOPING COUNTRIES[a]

Description of Tractor and Components	Cost
	dollars
Main Frame: Includes - differential housing, belt and chain guards, seat and spring, fenders, [illegible]bar and lift lever, foot-operated clutch and [illegible], two steel sprockets and roller chain, tool b[illegible], steering wheel, four sheaves, and belt and hand-operated emergency brake	186.00
Rear axle assembly	62.50
Three speed transmission, one reverse	54.00
Front axle, spindles and four timken bearings	22.40
12 hp. Kohler gasoline engine	106.00
Hood over engine and throttle	15.50
Wheels and tires: rear - 800 x 16, front - 4.00 x 8	96.25
Front counterweight box ($3.50)	no charge
Swinging draw-bar ($6.60)	no charge
Total Net Cost (FOB, Waverly, Iowa)	542.65

[a] Self-help Organization, Waverly, Iowa, *Price List and Specifications*, March, 1967.

A variety of tools is available for the Self-Helper to perform almost any basic farm operation. More tests under tropical conditions in Equatorial Africa are needed to determine performance and desirability. Rooney says that the tractor is powerful for its size and has performed well under Ethiopian conditions.[171] However, *no matter how simple or rugged a machine or tool may be, periodic attention is required.*

Implements may be rear-, center-, or front-mounted; are controlled by one handle; and are quickly adjustable or removable. Not all the following attachments are recommended or suitable for the small farmer. All prices are FOB, Waverly, Iowa with freight costs to Africa adding about 25 to 30 percent to factory prices. A partial list of attachments for the Self-Helper follows:

1. The moldboard plow cuts a 30 cm. furrow to 18 cm. deep. Raised and lowered by a hand-lift lever, it is completely adjustable. Plow body has replaceable share and is equipped with 25 cm. coulter blade. Weight is 43 kg. and price $50. (Figure 3.59.)

2. The cultivator is a spring tine unit with six shovels, sweep type, adjustable three-ways and rear-mounted. Weight is 27 kg. and price $26.50.

3. The drag harrow is a pull-type spike-tooth unit with 5 bars and 35 teeth. The flexible frame is 122 cm. long by 148 cm. wide. Weight is 55 kg. and price $20.00.

4. The disk harrow is a single-gang harrow with ten 35 cm. or 40 cm. diameter blades mounted on four bearings. Blades can be adjusted for cutting angle and weight added to gang platform. Maximum cut is 153 cm., weight 138 kg. and price $85.00. (Figure 3.60.)

5. The furrower or ridger is a rear-mounted unit hoe with a 25 cm. furrow shovel, heavy-duty shank, adjustable beam and hand lift. Weight is 30 kg. and price $26.00.

6. The seed planter is a one-row unit equipped with fertilizer attachment and ground-press wheel with chain drive. Four quick-change seed plates and three spacing gears permit planting a variety of crops at selected distances. Weight is 54 kg. and price $95.00.

7. The rotary mower, a center-mounted twin-rotor blade mower, cuts a 112 cm. swath. Weight is 55 kg. and price $145.00.

8. The sickle bar-mower, a center-mounted mower, cuts 105 cm. and is driven directly from the engine. It features a counter-balanced flywheel, hardened gears and enclosed transmission running in oil. Weight is 45 kg. and price $165.00. (Figure 3.59.)

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[171] Robert Rooney, Farm Machinery Advisor, USAID Mission, Addis Ababa, Ethiopia, Personal Communication, February, 1969.

Figure 3.60 Self Helper tractor disk harrowing in Ethiopian highlands
This 12 hp. tractor did a very acceptable job of breaking up a field of grass and weeds at the Debre Zeit Agricultural Experiment Station in central Ethiopia. Self Helper and its tools can be supplied disassembled to developing countries. It has not been thoroughly tested and evaluated in Equatorial Africa. (Photo courtesy of R.P. Rooney, USAID/Ethiopia, Addis Ababa, Ethiopia, April, 1969) (AFR-546.)

9. A 5 cm. outlet irrigation pump can be mounted on the front of the tractor and belted to the engine. Capacity is 530 liters per minute. Weight is 55 kg. and price $135.00.

10. A dump-cart kit, with load-carrying capacity of the 8 cm. channel iron frame, is 680 kg. on new 500 x 15 tires and roller-bearing wheels. Rear hinges and dump latch are included for local construction of the box. Weight is 50 kg. and price is $75.00 for frame and wheels. Cost of local materials to build a box in Ethiopia was $25.00.

b) Boshoff's Tractor In communication with Makerere University College, University of East Africa, the Team was furnished information by Boshoff on the assembly of several types of small tractors of 7 to 10 hp. from standard components.[172] The parts are purchased from countries which offer the best selection and prices; the intention is to distribute the tractors to progressive farmers in developing countries. Two tractors will have mechanical transmissions and one will have a hydrostatic transmission made by Bolens. Tractors will be powered by Kohler, Wisconsin, or Clinton engines.

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[172] W.H. Boshoff, Agricultural Engineering Department, Makerere University College, Faculty of Agriculture, University of East Africa, Personal Communication, February, 1968.

Boshoff's goal is to produce a basic tractor for about $550 to $600, using local personnel to construct the chassis and mount the various purchased components. Initially he plans to use 12 technicians, assisted by students in off-season, to build 40 to 60 units a year. With sufficient demand, he hopes to get the government or private industry to take over the tractor's assembly and manufacture. Along with the tractor, he plans to build or furnish a rotary slasher and rotary cultivator for another $200 to $250 for a total price of $750 to $850. The first of the three tractors is assembled and ready for tests.[173]

The approximate costs to build a small tractor in eastern Africa from imported components without duty or profit and excluding dealers' margins are:

Gearbox and transmission	$ 300.
Wheels, tires; axles	30. to 50.
Engine, air-cooled, 7 to 10 hp.	75. to 100.
Frame, steering, controls	75.
Labor and assembly	75.
Estimated total net cost	$ 555. to 600.

Handling by a dealer organization would require a reasonable mark-up for incentive to stock parts and properly service this equipment. The final price to the farmer would be at least one-fourth more.

c) <u>Economy Tractor</u> Jim Dandy, standard model, is equipped with 12 hp. Kohler K 301 engine, front power-take-off, rope starter, hand brakes, fenders, automotive-type steering, 400 x 8 front and 700 x 16 rear tires. Weight is 287 kg. and list price $724 at factory, Wankesha, Wisconsin.

Accessories needed are an equipment lift-lever ($15) and a rear toolhitch ($20). Some attachments available are a 25-cm. turning plow with coulter, 36 kg. (factory price $76); disk harrow, sectional adjustable, eight disks 40 cm. diameter, weight 67 kg. ($168); cultivator and spring-tooth harrow, six shovels, 105 kg. wide, weight 36 kg. ($42); rotary mower, 120 cm. cut, three blades with guards, weight 78 kg. ($155). (Figure 3.61.)

3) Small Threshers

A number of important pieces of equipment available for the progressive hand- and animal-powered farmer are small threshers, motorized back-pack sprayers, grinders or hammer mills, seed cleaners and irrigation pumps.

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[173] *Ibid.*, March, 1969.

Figure 3.61 Economy (United States) "Jim Dandy" 12-hp. tractor with rotary mower This tractor is similar to the Self Helper in concept with a complete line of small implements. A little more elaborate and consequently more expensive it incorporates some features not essential to farmers in developing countries. When properly applied and carefully maintained it could do considerable work but like every other machine it needs substantial back-up service and logistic support. (AFR-511)

a) Garvie Mini-thresher Manufactured by R. G. Garvie and Sons, Aberdeen, Scotland this unit can be produced by light industry in developing countries under free license from the National Institute of Agricultural Engineering, Silsoe, Bedfordshire, England.[174] The machine consists of two basic units, the threshing- and grain-collecting assemblies, simply constructed of angle iron and sheet steel. The total weight is 153 kg. The thresher consists of a 30 cm. diameter steel drum with three rasp-bars and an open-wire concave. The drum is driven by a four-stroke 2-1/3 hp. petrol engine at a peripheral speed of 1,442 meters per minute. The material fed into the machine by hand is ejected into the collecting box, where the straw is manually raked away from the grain. Haynes reported:

> With the recommended concave clearances and drum speeds, the amount of grain damage was found to be well under one percent. The rate of output of threshed rice is very dependent on the crop yield and the number of men available to feed the machine. Under reasonable conditions outputs of the order of

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[174] National Institute of Agricultural Engineering, *Mini-thresher*, Bulletin No. 3, (Silsoe, England: Overseas Liaison Unit).

450 to 680 kg. of threshed rice per hour were achieved, using five operators. This includes all operations from picking the cut rice up from the field to bagging up the threshed grains.[175]

Many other varieties of crops including wheat, peas and beans have been successfully handled. Several are in use in England as plot threshers at research stations and seed merchants. Some 500 of these machines have been used since 1964 by farmers in Malaysia.

b) Comparison of Garvie, Pioneer and Turner Small Threshers In a test in Northeast Nigeria, Shambaugh reported:[176]

1. The Garvie thresher was suitable for rice but did not work well with other crops. It took a lot of man-power besides considerable machine work. It was able to handle guinea corn and millet by running it through twice.

2. The Pioneer thresher was satisfactory for rice. The main problem is that the straw walker does not move sufficiently. It cannot be used for groundnuts since the straw will not move through the machine.

3. The Turner economy thresher did an acceptable job with grains and can be used also for groundnuts by modifying the tooth cylinder. For a satisfactory job, guinea corn and millet must be run through twice. It would work better if it had a separate belt from the main pulley to the cylinder so that the cylinder speed could be changed without affecting the straw-rack speed. The latter can be varied only about 20 cycles per minute. Shambaugh suggests that a 46 cm. diameter main pulley be used.[177]

c) Kyowa Double-drum Thresher This unit was tested by the TAMTU in Tanzania on rice.[178] It is intended for rice, wheat and barley with straw cut long or short. The sheet-metal body contains two drums 70 cm. long, one 32 cm. in diameter and the other 24.5 cm. diameter, both equipped with looped-wire threshing teeth. Two concaves of open wire have four cutting blades in each chamber. The drum/concave clearance is 7.5 cm. nonadjustable. Two threshing chambers are 38 cm. wide. The machine weighs 146 kg. and is transported by two iron carrying rods. Power required was 6 hp. to operate thresher at 720 rpm. The "closed medium" speed setting produced the best quality sample with 98.53 percent pure clean grain and only 0.71 percent broken kernels. Capacity was 52 kg. per hour.

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[175] Haynes, *A Brief Review of Mechanization Experiments in Northern Nigeria*, Appendix A, p. 13.

[176] T.J. Shambaugh, Jr., Farm Industry Advisor (USAID) to Industrial Development Center, Samaru, Nigeria, Personal Communication, November, 1968.

[177] *Ibid.*

[178] Ministry of Agriculture, Forestry and Wildlife of Tanzania, *Test Report No. 19/66/67*, (Tenguru, Arusha, Tanzania: Northern Research Center, TAMTU).

Testers concluded the high cost of machine and engine makes it uneconomical for individual farms, but it is suited for cooperatively-run farms where the crop is large enough to make the enterprise profitable. Modifications were suggested for safety.

d) Small Stationary Thresher Many farmers in northwest Ethiopia are threshing sorghum by hand. A few like Markos Sideris have small, old Italian stationary threshers which they pull around from field to field. The sorghum heads are cut off close to the top with machetes or sickles and are placed in large piles scattered over the field. The thresher is belt-driven by a 45 to 50 hp. tractor and is hand fed by pouring baskets of grain into the cylinder. The grain is removed and bagged by hand. (Figure 3.62.)

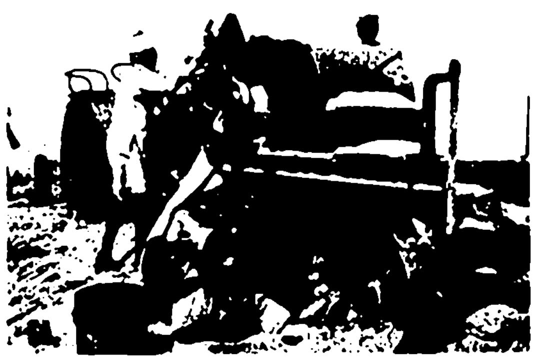

Figure 3.62 Threshing in Ethiopia While most threshing is still done by hand and animal trampling, a few of the larger farmers in the commercial farming areas of northwest Ethiopia use mechanical means. This Italian stationary Balouzzi-Rovida thresher is being used to thresh sorghum. The heads are cut off by hand and thrown in large piles. The threshing rig is moved once or twice a day. Threshing capacity is 2000 to 3000 kg. per eight-hour day. (AFR-153)

4) Sprayers and Dusters

a) Solo Junior 410 This is a motorized back-pack sprayer mist-blower made by Solo Kleinmortoren GMBH, Maichingen, West Germany. Powered by a 2 hp. two-cycle engine, it operates at 700 rpm. on about 0.93 liters per hour. The 8.3 liter liquid tank and frame are molded from one piece of light-weight plastic and weigh 7.5 kg. complere with engine. The engine features the ignition magneto cast into the fan-wheel. The unit is very compact and has the center of gravity near the back of the carrier. A valve in the air-hose acts as the throttle. To spray or dust, the valve is

opened to accelerate the unit and closed to shut off the spray. The nozzle has four settings for direct spray of 0.58; 1.08; 1.78; or 2.36, liters per minute.

TAMTU tested this unit and reported the calculated velocity of spray liquid was 66 meters per second, giving a coverage of 606 cubic meters without nozzle and 354 cubic meters of effective delivery with it. The average pressure of 10 psi gave 3.37 meters of spray mist and TAMTU says various tests proved the machine quite satisfactory: it was easy to carry; simple to operate; and a wide range of volume adjustment to suit different crop stages provided sufficient liquid dispersion for good leaf coverage. The machine is rigid, its workmanship good and there were no breakdowns or trouble of any kind.

TAMTU concluded,

> If it sells at a [reasonable] price in comparison with other sprayers in the market, the "Solo Motor" will prove extremely economical to Tanzanian farmers for all its advantages listed . . . Recommendation: This machine, given the necessary attention, will serve for the whole cropping season trouble-free, and we would, therefore, recommend it to farmers, particularly those investing their money in cash crops and food crops of any kind, and for other applications, *viz.* tsetse control and forest husbandry.[179]

b) <u>Solo Combi 423 Sprayer Duster</u> This machine is designed for either mist- or dust-spraying and is similar to the Solo Junior 410 but slightly smaller in size. Powered by a two-cycle 1.5 hp. engine its empty weight is 7.75 kg. and weight, filled with liquid, is 19.75 kg. TAMTU also tested this machine for suitability to Tanzanian conditions.[180] They reported leaf coverage was 87 percent and said,

> The implement proved satisfactory for the work it is intended for in conjunction with the following advantages: light weight, simplified operation, sufficient liquid dispersion, spray pattern being easily adjusted, good construction and workmanship . . . Given the right attention as per leaflet provided [it] can be trouble-free at a considerable economic usage. If the purchase price is moderate the machine is highly recommended.[181]

c) <u>Silon Knapsack Mist- and Dust-blower</u> This combination machine designed for field and tree crops is manufactured by Metal Works, Nir-David, Gilboa, Israel. Two models are available: L35 with 1.7 hp. engine operating

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[179] Ministry of Agriculture, Forestry and Wildlife of Tanzania, *Test Report* No. 12/66/67/A, (Tenguru, Arusha, Tanzania: Northern Research Center, TAMTU, March, 1967).

[180] Ministry of Agriculture, Forestry and Wildlife of Tanzania, *Test Report* No. 12/66/67/B, (Tenguru, Arusha, Tanzania: Northern Research Center, TAMTU, March, 1967).

[181] *Ibid.*, p. 4.

at 6000 rpm; Model L77 with 3-hp. engine running at 5000 rpm. The frame and blower are made of aluminum; and the liquid or dust tank from plastic. Air volume is 150 liters per second and fuel consumption under one pint per hour. The blower features fast and simple conversion from sprayer to duster or vise versa without tools. Empty weight is 11 kg. and price in Ethiopia $128.00.

d) General Characteristics of Knapsack Mist Blowers The Tropical Pesticides Research Institute (TPRI) has made extensive tests of spraying equipment in cooperation with other research stations in East Africa. They have published numerous reports and a general review of their work is contained in a report made to the Specialists Committee on Agricultural Machinery in March, 1965.[182] In general, they say of motorized knapsack mist blowers (Figure 3.63):

> Engine speed decreases with increasing altitude and a reduction of 10 percent can be expected at 5000 A.S.L. (feet above sea level, equal to 1530 meters) . . . Measurements of air velocity four feet [1.22 meters] from a stationary machine indicate that a 90 percent reduction in velocity takes place at this point. A range of spray outputs is usually achieved by fitting different restrictors, only four restrictors are usually available. However, liquid output is critically affected by the inclination of the lance (or discharge air tube) being markedly reduced as the lance is raised above the horizontal level. Output falls to 60 percent of normal figure when the lance is directed to the top of a 15 foot [4.6 meters] coffee tree, and in some cases reduction in excess of 50 percent occurs when lances are raised vertically . . . Droplet sizes of mist blowers are, as their name suggests, much smaller than those produced by conventional compression and hydraulic sprayers. An approximate guide to their droplet performance is as follows: for liquid outputs of 1-2 pints per minute and 2-4 pints per minute, the main droplet size is in the range of 80-130 and 130-170 microns, respectively.[183]

TPRI reported satisfactory control of disease and insects on coffee, which is one of the main cash crops in East Africa. In Kenya, leaf rust has been satisfactorily controlled by well-timed applications of copper fungicides to arabica coffee, using approximately 93.5 liters per hectare, while in Tanzania, applications of only 65.5 liters per hectare proved as effective as conventional treatments of 1122 liters per hectare. In Uganda, a 91 percent reduction of antestia has been achieved by applications of approximately 168 liters per hectare (2471 trees per hectare equivalent).[184]

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[182] C.W. Lee, *A Review of Spraying Machinery Trials in East Africa*, Miscellaneous Report No. 500, (mimeographed) (N'oro, Kenya: Egerton College, Agricultural Machinery Specialist Committee, 1965), p. 6.

[183] *Ibid.*, pp. 3-4.

[184] *Ibid.*, p. 4.

Figure 3.63 A Solo mist blower used by the Plantation Crops Department of the University of Science and Technology at Kumasi, Ghana These motor driven back-pack units are very effective for small plantations to control insects and disease in cocoa, coffee, tea and other crops. They are available from German, Dutch, English and Japanese manufacturers, and are used extensively in eastern Africa for insect control in coffee and cotton. (AFR-166)

5) Grinding and Processing Equipment

a) Small Scotmec Popular Hammer Mill The mill has eight swinging hammers directly coupled to a Briggs and Stratton 3 1/2 hp. four-stroke petrol engine. Mounted on a pipe pedestal with tripod base, it has a sheet metal feed hopper and direct bagging attachment at the bottom of the mill. Full circle screens are sized from 0.59 to 12.7 mm. diameter holes. Haynes reported that the hammers are reversible four times and total life should exceed 35 tons of grinding. This mill is reported no longer manufactured but similar models are available. Price was $224 for the mill and $8.40 for extra screens in Nigeria.

TABLE III. 23 OUTPUT OF SCOTMET POPULAR HAMMER MILL WITH 3 1/2 HP. PETROL (GASOLINE) ENGINE[a]

Screen size	Output of flour	Fuel consumption
	kg./hr.	liters/hr.
0.59 mm. hole	170 kg.	2.65 liters
1.04 mm. hole	218 kg.	2.27 liters

[a]Haynes, *Interim Report on Tests on Ox-drawn Implements as Groundnut Lifters*, p. 79.

One pass through the mill with 1.04 mm. screen gave flour comparable to that obtained with two passes through a plate mill. It can grind dry guinea corn, millet and maize. Soaked guinea corn, maize and groundnuts were ground satisfactorily when extra water was fed into the hopper. In conclusion, Haynes says, "The Scotmec Popular Hammer mill has about the same output as a plate mill with an 8 hp. diesel engine and is suitable for similar duties." It is recommended for milling for human consumption with the 1.04 mm. hole diameter screen and for milling small quantities of stock feed with the 6.35 mm. hole screen.[185]

b) Kirloskar and SISCOMA Groundnut Decorticators Dr. W. D. Wadhwa in Ghana is selling several models of power-driven groundnut shellers imported from India as well as other processing machines. He plans to manufacture the Indian models in Ghana.[186]

Kolyan A can be hand-operated or powered by a 5 hp. engine. The suggested engine is the Kirloskar water-cooled vertical diesel AVI running at 1500 rpm. Capacity of the machine is 650 to 700 kg. of groundnut pods per hour. The price in Accra is $1,030.00 with a 5 hp. engine.

Kolyan, a power-driven groundnut decorticator has a separator and brackets for removing clods and stones from groundnut pods. The suggested engine is the Kirloskar water-cooled vertical diesel model JUZ rated at 13-Bhp at 1500 rpm. Estimated capacity is 1000 to 1300 kg. per hour. The price in Accra is $2,530.00 with engine.

SISCOMA Super Victory decorticator is a rotary decorticator powered by a small engine or by hand. Output is 140 to 160 kg. per hour with 88 to 92 percent of the nuts commercial saleable, 7.5 percent cracked and damaged and 1 to 2 percent waste. Current price is unknown.

c) Wadhwa Cassava Grater Manufactured locally by Agricultural Engineers Ltd., in Accra, this machine is an original design by Dr. Wadhwa. It is suitable for making starch, mashed yam, *gari*, *kokontey*, and *mori*. It has three circular plates for grating coarse, fine or superfine. With a 5 hp. engine its cassava output is 900 kg. per hour. The Accra price with the 5 hp. Kirloskar diesel engine is $687.00 or $192.00 without engine. (Figure 3.64.)

d) Palm-nut Crackers The Wadhwa cracker is another original machine made by Wadhwa. Powered by a 5 hp. engine at 1500 rpm., its

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[185] *Ibid.*, pp. 79-80.

[186] W.D. Wadhwa, Managing Director, Agricultural Engineers Ltd., Accra, Ghana, Personal Communication, November, 1968.

Figure 3.64 Wadhwa's cassava grater; Accra, Ghana Wadhwa's prototype model of a cassava grater powered by a 5 hp. water-cooled German-made diesel engine of Indian design has a capacity of 900 to 1800 kgs. per hour. The cassava roots are fed into the top against the vertical grating cylinder and discharged out the bottom one side. (AFR-257)

estimated capacity is roughly 500 to 700 kg. of nuts per hour. The price in Ghana with Kirloskar engine is $730.00.

The SISCOMA "Colin" cracker, a portable self-contained cracker, has been developed by SISCOMA with the cracking hammers mounted directly on the engine crankshaft mounted on wheels. The entire unit weighs 139 kg. Powered by a 3 hp. engine with a special air filter its output is 300 to 400 kg. of nuts per hour. The quoted price in Dakar was $506.00.

e) Maize Shellers Several models are being sold in eastern and western Africa but detailed specifications were not available.

The Wadhwa sheller is power operated; the price with engine is about $245.00.

The Amiran maize sheller, a simple platform-mounted single-ear sheller, is available from Alda Ltd., an Israeli Company with branches in eastern Africa. Powered by a small 2 1/2 hp. Clinton engine, it has an estimated output of 400 to 450 kg. per hour. The price with engine is about $260.00 in Ethiopia. It is light enough to be moved around from farm to farm by four men.

f) Sugar-cane Crushers The Koyna is a horizontal three-roller model powered by a 5 hp. engine; the capacity is 320 to 430 kg. of sugar cane per hour. The price with the Kirloskar 5 hp. diesel engine is about $1,310.00.

The Sharat No. 2A is a horizontal three-roller model powered by a 10 hp. engine, with a capacity of 545 to 680 kg. of sugar cane per hour. The price with the Kirloskar 10 hp. diesel engine is about $1,752.00.

g) Irrigation Pumps There are several types of pumps.

The Kirloskar diesel pump Set No. 1, sold by Agricultural Engineers Ltd., Accra, Ghana, is an end-suction, single-stage, horizontal bareshaft centrifugal pump. It is mounted on a common base and coupled to a Kirloskar cold-starting, water-cooled, single-cylinder, compression-ignition, four-stroke cycle diesel engine. The pump is water cooled with a suitable screw and foot valve. The capacity of the 7.6 x 7.6 cm. centrifugal pump at 9.2 to 16.8 meters of total head and 1500 rpm. is 379 to 928 liters per minute. The Ghana price with engine is $606.00, plus $60.00 for accessories consisting of 7.6 meters of suction hose, 15.3 meters of delivery hose and bends (Figure 3.65.)

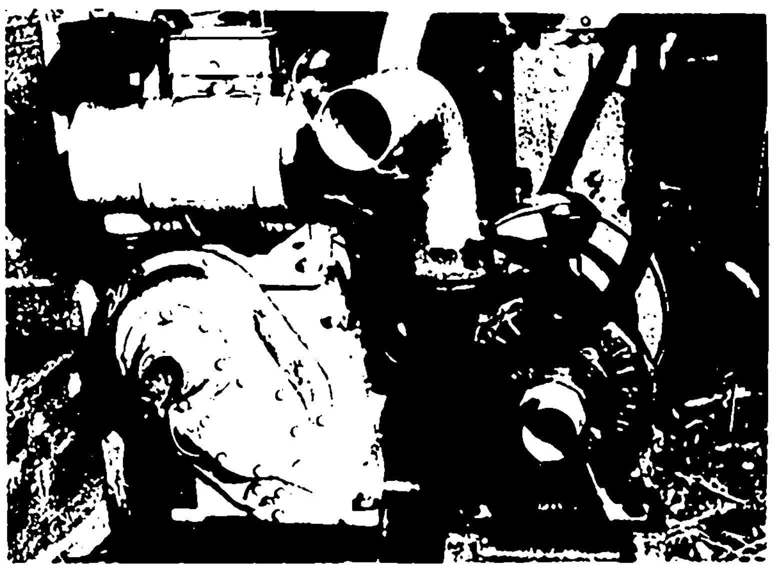

Figure 3.65 Kirloskar (Indian) diesel-powered irrigation pump seen in Ghana This type of pump with self-contained engine can be used for supplying one of the major limiting factors to increased production in Equatorial Africa. Throughout the tropics there are few areas which receive sufficient rainfall for year-round crop production. Distinct wet and dry seasons require development of water resources if more than one crop is to be grown and if adequate control is to be exercised over high-value crops. High-yielding varieties which make maximum use of fertilizer and other agricultural inputs can be grown in multiple-cropping programs if irrigation can be supplied at reasonable costs. (AFR-365)

The Kirloskar diesel pump Set No. 2 is similar to the pump above except for a 6.4 cm. x 5.1 cm. bareshaft centrifugal pump. At 1500 rpm. against a total head of 12.2 to 21.4 meters, the discharge output is 303 to 530 liters per minute. The price is $606.00 plus $60.00 for hose and couplings.

The Singer Company markets a small direct-drive centrifugal irrigation pump with self-contained engine and stand, in addition to the outboard-drive models used with the "Landmaster" two-wheel tractor. Various outputs are available for agricultural and domestic purposes. The price of a 5 by 5 cm. irrigation pump without engine is about $175.00.

The Middle Awash Settlement Scheme in Ethiopia uses four diesel engine powered portable Same pumps for pumping water into a main canal for flood-irrigating maize and cotton. Pump capacity is approximately 3030 liters per minute. (Figure 3.66.)

Figure 3.66 Melka Werer Research Station pumping site on the Awash River
The concrete apron on which the pumps stand is being extended and the gradient in the foreground concreted. This permits the pumps to be easily raised when the river floods. This area receives only 10 cm. average annual rainfall so that water supply and control are major factors in the development of the fertile soil. (AFR-224)

6) Output, Power, Capacity and Labor Required

a) Small Tractors: Two-Wheeled For the Titan Merry Tiller, according to Cooper, rate of work varied from 47 to 950 square meters per hour according to the type of work done, soil conditions, depth of work and

experience of operators.[187] Fuel consumption varied from 0.43 to 1.04 liters per hour. The power unit was considered adequate for general conditions with the V-belt drive used at its lowest speed to produce a satisfactory tilth. When the high speed was used, there was a tendency to break the soil-crumb structure and overload the engine if six rotors were used to depths of over 15 cm. at high altitudes. With regard to capacity and effectiveness for farm operations, Cooper said:

> After rain fell, the soil was worked to a depth of about 15 cm. During secondary cultivations, thick lush stands of weeds up to 15 cm. high (mainly *amaranthus*, Mexican marigold and *cleavers*) were satisfactorily chopped and mixed into the soil with very little blockage. An old pasture field, which was badly infested with wire grass 'tussocks' had been plowed two months previously with a disk plough and left in a rough state, was broken down and left in suitable condition for planting in one pass. Inter-row cultivation of maize was carried out efficiently after the maize plants had reached the height of 15 cm.; the soil 'cap' was effectively broken and most of the weeds were destroyed.
>
> The movement of soil to the plants was a good feature in smothering weed growth between the plants and for the prevention of soil erosion, but when done while the maize seedlings were very small, there was a danger in smothering them. Traction was good in most conditions but 'fluffy' patches in volcanic soils caused the machine to dig in and occasionally required a little help from the operator to maintain forward movement.[188]

The only available data on some typical field capacities and outputs for the Landmaster 150 tractor were measured by Rao (operations in India):[189]

1. Dry-land Moldboard Plowing: Capacity per eight-hour day equaled 0.2 to 0.4 hectares per day. Time was about 20 to 30 hours per hectare for average light-soil conditions, and up to 37 hours per hectare or more under severe conditions.

2. Puddling and Leveling Rice Paddy: About 0.4 to 1.4 hectares per day or 6.0 to 20 hours per hectare; actual time on different soils varied from 5.5 to 24.7 hours per hectare.

3. Ridging: The output was about 1,225 meters of ridge per hour when conditions were favorable. Ridge size was 27 cm. from bottom of furrow to crest on plowed land.

4. Rotary Cultivating: Output was 0.4 to 0.8 hectares per day under most conditions, dropping to 0.27 hectares per day when going was difficult.

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[187] Cooper, *Test Report on a Walking Tractor*, p. 1.

[188] *Ibid.*

[189] E.G.K. Rao, "*Mechanization for Small Holdings Having Intensive Cultivation of Crops and for Hilly Areas*, (New Delhi: India Agricultural Research Institute, n.d.)

Actual time ranged from 10 hours per hectare up to a high of 29.6 hours. Farmers in the Meru area of Kenya are cultivating around their coffee and fruit trees. Parkins says they can cover 0.8 hectares per day containing 700 trees at a fuel-cost of 9.36 liters per hectare or about $1.40 per hectare. To hire this work done by hand cost 10¢ per tree for 700 trees or $71.00. One Landmaster tractor also can weed 1.2 hectares of sugar cane a day.[190]

5. Irrigation Pumping: At 2500 to 3500 rpm. engine speed, the 5 cm. outlet pump delivers according to the manufacturer:

180 liters/min. against 21.4 meters total head
360 liters/min. against 16.8 meters total head
450 liters/min. against 12.2 meters total head

6. Crop Cutting: With 91-cm. cut at low speed, capacity is 1.6 hectares per day or five hours per hectare.

7. Threshing: Up to 1,360 kg. of rice can be threshed per hour, depending on yield, dryness and maturity of the crop.[191]

b) Small Tractors: Four-Wheel Test reports or data on work capacities of the smaller four-wheel 7 to 12-hp. riding tractors were not available in Africa. Apparently no one has tested their suitability for use by small farmers. While it is believed they have a place under conditions of good local service and with proper training, no operation costs or capacities are available to substantiate claims. This is an area of investigation sorely needed and one which could be conducted effectively by national research centers or investigative groups.

7) Skill and Management of Small Tractors

a) Small Tractors: Single-Axle, Two-Wheel In a test of the Titan Merry Tiller, Cooper says,[192]

> *As with most motorized cultivators, the quality of work depended largely on the operator's desire to produce good results.* Under the conditions encountered during the test the machine was capable of producing good work, and at no time was the tilth over-worked. When used to break Rhodes grass and Kikuyu grass pastures, it was necessary to reduce the number of rotors to four to achieve penetration. Most of this work was done when the ground was in a hard dry compacted state in preparation for the main growing season, thus the penetration was restricted to 7 to 10 cm. but, while this task was tedious, the grass kill was most effective.

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[190] Kenneth Parkins, Landmaster Agent, Singer Sewing Machine Co., Nairobi, Kenya, Personal Communication, October, 1968.

[191] *Ibid.*

[192] S.W. Cooper, *Test Report on a Walking Tractor*, p. 1. (Italics added by author of this Chapter.)

> Generally, *the machine was easy to handle by experienced operators*; most operators became familiar with its handling characteristics after about one hour's practice. It was found that an operator could control it very accurately for inter-row work; if there was any narrowing of the rows a rotor could be removed in one minute thereby reducing the working width of the machine. In a similar time the machine could be converted to its original width.
>
> When working on sloping land the machine was easier to handle by working downwards across the slope. Slight sideways movement assisted penetration in hard conditions.

In using small tractors or rotary cultivators like the Landmaster 150, good judgment and common sense are required to adapt the machine to special conditions and to obtain the best performance. These small machines have adequate power when properly applied. First-hand experience in the field is the best way for farmers to learn, but certain pointers can be taught to the beginning operator to avoid unnecessary difficulties and frustrations. The proper selection and use of tools and attachments properly matched to soils, vegetative conditions, engine-power, and speed will provide satisfactory performance.

In dry-land plowing, when weighted rubber tires will not grip, steel plowing wheels can be used at slow speeds. In wet-land plowing in very stiff soil, wheel weights can be used with rubber tires to advantage; in very soft soil a wide puddling-wheel (about 45 cm.) can be used on the left side only. In rotary cultivation curved blades are best for medium soils, inter-row weed control and shallow cultivation. Slasher-type blades are needed for heavy, hard soils, heavy, wet clay soils and heavy weed growth. Blades should be staggered to form a spiral around the axle. The proper height in walking tractors is important to the operator's comfort and control. If too high or too low early fatigue will be caused. In threshing, maximum efficiency depends upon feeding the crop into the cylinder evenly and continuously. The correct concave to drum clearance must be set at the recommended distance (6.3 mm. for rice on the Landmaster thresher) for proper threshing. The engine also must be regulated to give the proper speed of 1500 rpm. under load. In operating small two-cycle engines, the correct oil and gas mixture must be used and kept absolutely clean. A special container should be used to prevent confusing the fuel mixture with other materials such as insecticide, fly spray, oil or plain gasoline. Under dusty conditions, air cleaners must be serviced frequently, especially units located close to the ground on small tractors. This may require more than one daily service.

Large Engine-powered Machinery

1) Tractors

The most common tractors in Equatorial Africa are the standard utility-type four-wheel tractors with 50 to 65 hp. diesel engines. Some tractors are equipped with four-wheel drive, including the Same, Fiat, Universal and Utos. The trend is toward large tractors. Distributors in Ethiopia and East Africa report the major demand is for the 65 hp. size, with preference in many places for the recently introduced 70 hp. models. Wherever tractors are properly managed and maintained on commercial-type operations, maximum use is made of skilled operators by increasing tractor size.

In Kenya, for example, one large farmer replaced four smaller 45 to 50 hp. tractors and four operators with one large 110 hp. tractor and one man. The farmer stated that more work is done at a substantial saving in operating and labor costs.[193] Th s applies only to large farms generally operated by expatriates. These farmers also have organized their farms to complement the use of large machinery by making long fields, generally of 20 hectares or more; by providing good access; by clearing fields of all obstacles; by making land improvements such as drainage ditches to minimize wet spots and by building diversion terraces and bunds for water control.

These large tractors (110 hp.) are used primarily for plowing and land preparation. The farm unit has to be large to employ them economically, or they have to be used on contract work for others. Several large contractors, private Swedish and Asian as well as the Ministry of Agriculture in Kenya, have purchased large units to plow land for the Masai Wheat Scheme and land formerly farmed on a share cropping basis.

For the larger African farmer or farmer-contractor in eastern Africa, the middle-size 50 to 65 hp. model is ample to meet most requirements when properly operated and fully utilized. (Figure 3.67.) Unless the contractor can find enough work on large farms, or plow large blocks for group or cooperative farms, he will not be able to effectively employ a larger tractor unit. There will be too much time lost in turning, starting and finishing, traveling between small lots, and wasted making agreements and trying to collect bills. In northern Nigeria where the soils are quite light, Hewitt said the small 45 hp. tractor such as the MF-135 was the most popular size.[194] Under these conditions, especially where tillage depth is limited by shallow

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[193] C.M. Downing, FAO Machinery Advisor, Ministry of Agriculture, Nairobi, Kenya, Personal Communication, October, 1968.

[194] P. Hewitt, General Manager, British East and West Africa Company (Massey-Ferguson) Apapa, Nigeria, Personal Communication, November, 1968.

Figure 3.67 Tractor use in Ethiopia Some Ethiopian farmers are purchasing modern implements and tractors. Two employees are drilling cabbage for seed on a private farm north of Asella in south central Ethiopia. They are seeding without fertilizer although tests have not been made for deficient elements. The concepts of row planting and mechanical sowing are new to most farmers and represent major changes. (AFR-232)

topsoils, this tractor can cover almost as much ground as the larger 65 hp. tractor working heavy, sticky, or hard clay soils at the high altitudes found in many parts of eastern Africa.

In Ghana, most of the wheel-tractors are Czechoslovakian Zetor Super-50's owned by the government. They were purchased in the early 1960's to provide a tractor-hire service to farmers. These units are 50 hp. in size; and when properly maintained and used with suitable implements in good repair, they are capable of doing satisfactory work. Unfortunately, maintenance has been deficient and certain critical parts remain in very short supply so that a majority of the tractors and implements are unserviceable.[195] (Figure 3.68.)

The same situation exists to a lesser degree in Nigeria where most of the tractors and machines are British or American. Many units are in disrepair because of parts shortages due to import restriction, too many makes and models, and lack of finances as a result of the current situation.

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[195] Max Starnes, USAID Farm Machinery Advisor, Survey of Northern Region, Ghana, Personal Communication, October, 1968.

Figure 3.68 Tractor repair workshop A few of several hundred 35 and 50-hp. wheel tractors brought in for repair from Workers Brigades, Resettlement Schemes, Mechanization and Transport Pools, government State Farms in the Northern Region of Ghana. Most of these have less than 1000 hours of use and have been out of service for 3-6 years. Tires, tubes, batteries, generators, injectors and injector pumps are critical items in short supply. (AFR-261)

Preventive maintenance is a major problem throughout Equatorial Africa.

In Setit-Humera, Ethiopia, the average farmer claims use of his tractor about 1,000 hours per year, providing there are no breakdowns necessitating long repairs. The owner of the largest farm with 6,500 hectares, reported he averaged 1,800 hours per year per tractor with 20 tractors. The average life of his tractors is five to six years or about 8,000 to 10,000 hours. After the second year of operation, at 3,500 to 4,000 hours of use, he overhauls each tractor completely; and thereafter every 2,000 hours. All major repair work is done at a private garage in Asmara. In 1967/68, it was difficult to purchase oil filters and fan belts, but this should be rectified in 1969 with the establishment of at least four major repair and service shops in Humera. Setit-Humera is a unique area of development and the largest farmer's record is far above average; the average Ethiopian farmer in this area probably averages only 50 to 60 percent service life.

2) Tillage Tools and Practices

a) Two-Spring Disk Plows Until 1967 the tractor disk-plow was used almost exclusively in eastern Africa and by the large plantations in Ethiopia. Since that time, a number of firms have tried and accepted moldboard plows.

Minto, Cooper, Downing and others still feel there is a place for the disk plow in Kenya; and one, the Buffalo, has been tested and rated as very good by the Kenya Agricultural Machinery Unit.[196] (Figure 3.69.)

In Ghana and Nigeria, the disk plow also predominates. The land requires 2 to 3 disk harrowings in order to prepare it. However, these repeated diskings tend to overwork the soil and thus subject it to erosion.

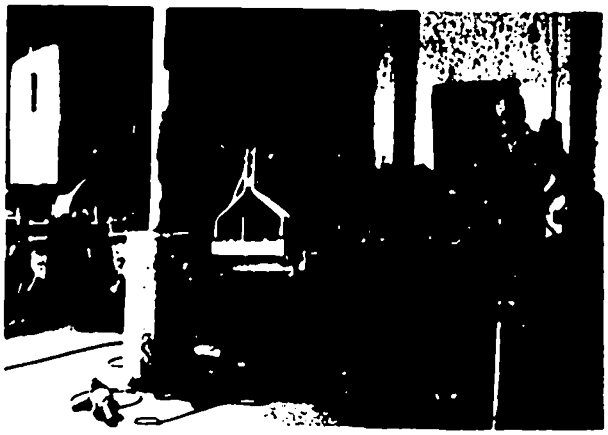

Figure 3.69 Buffalo (Kenya) heavy-duty disk plow made by small metal shop
This plow is an example of an agricultural tool built in eastern Africa which has successfully competed with major-line manufactured imported tools on the basis of quality and price without restrictive tariffs. Tested by Kenya Agricultural Machinery Unit this tractor implement performed very well and proved its suitability to East African conditions. (AFR-517)

b) Moldboard Plows Tractor plowing contests in Kenya, brought quick acceptance of moldboard plows due to their superior job of turning and burying trash. With the same horsepower tractor, they also increase the cutting width and the effective output of the tractor under good conditions. Because the moldboard does a better job in grasslands, it makes it possible to prepare land for planting with only one disking. After comparing the results of the plowing contests, quite a few contractors began offering moldboard plowing and charging more for it. (Figure 3.70.) When the tractor-hire services do a good job of plowing, the hand farmer can easily prepare the land for planting and he is willing to pay more. Larger farms and plantations, like Tendaho in Ethiopia, also are adopting the moldboard plow.

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[196] S.W. Cooper, *Expression of Opinion*, Report No. 866, (Kenya Agricultural Machinery Unit, n.d.).

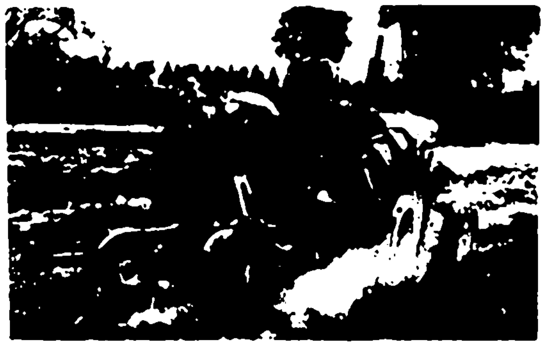

Figure 3.70 Moldboard plowing in East Africa Student from the Narosurra Farm Mechanization Training Scheme used this Danish plow to win the South African world plowing contest in 1967. The plow is being tested by the Kenya Agricultural Machinery Unit. In addition the effect of different types of tillage (disk plow versus moldboard) upon crop response is also being studied. (AFR-105)

c) Offset and Tandem Disk Harrows In Kenya the Tractor-hire Service has found the heavy-duty offset disk very effective in the Masai Wheat area. After disk plowing, the land is disked once or twice depending upon its condition. Downing says the best harrow to use with the Ford 5000 67 hp. tractors is the French-made International Harvester F-29 B, single-offset 285-cm. wide disk. (Figure 3.71.) Tandem transport-type disk harrows are used in many operations.

d) One-way, Wide-level Disk Harrow In large open plains areas of Ethiopia and Sudan, this tool is very popular. It is used on the vertisol soils which require only minimum tillage. Its primary purpose is to control weeds and to fill the deep cracks which occur as the soil dries out. Several common makes are John Deere, Massey-Ferguson, Cockshutt, and Nardi. The harrows generally have 18 to 24 disks 45 cm. in diameter and the average width of cut is 3 to 3.6 meters, respectively. (Figure 3.72.)

e) One-way Disk Plows In Kenya the large, one-way, Australian Conner-Shea disk plow does very good work in the mellow, friable wheat-land soils which pulverize easily. Each of the 24 disks is independently sprung, making it particularly good on slightly rolling land. It works best at a speed of 5.6 km. per hour. (Figure 3.73.) While quite expensive, it is very well-constructed and does an excellent job. Downing states that it triples the output of the Ford 5000 compared to the regular four-furrow disk plow.[197]

[197] Downing, *op. cit.*

Figure 3.71 Disk harrow used in Masai Wheat Scheme Disking for second (1968) crop on land first plowed in 1967. This type of disk harrow is popular with expatriate farmers and is being manufactured in Kenya by three firms. The Ministry of Agriculture rents the land from the Masai tribes, and does the organizing, planning, operating, producing and marketing for the crop. At the time of sale the MOA charges the farmers the actual cost of production and takes it out of the gross crop receipts. (AFR-100)

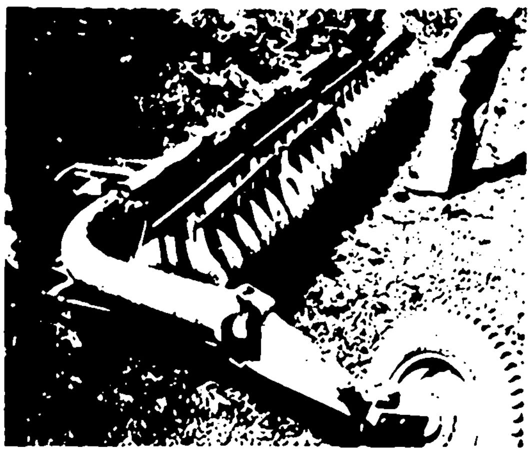

Figure 3.72 One-way, wide-level disk harrow (British) used in Ethiopia and Sudan This implement is the only tillage implement used in northwest Ethiopia and in parts of Sudan for the production of sorghum, cotton and sesame. The rich Vertisols tend to be self-mulching as they crack when they dry out. Preparation for seeding the next crop at the beginning of the rainy season primarily requires that the cracks be filled and weeds killed. When used in a good system of cultivation practices, weeds can be controlled within the limits of a minimum tillage program. In Ethiopia, the seed is broadcast and this same disk used for covering as the final operation. (AFR-13)

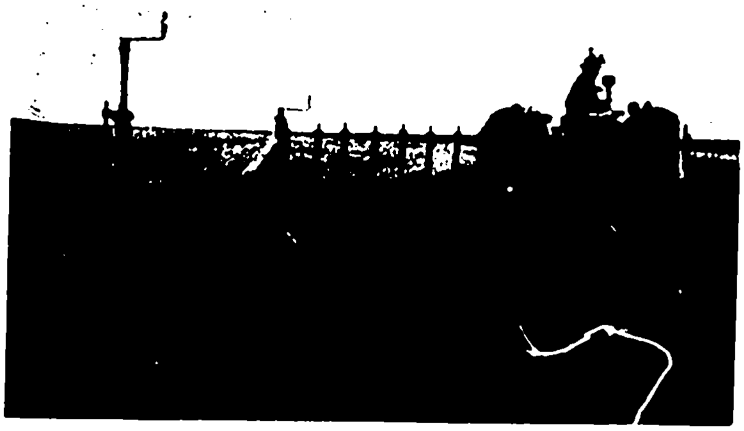

Figure 3.73 Australian-built Conner-Shea disk plow being used on Masai Wheat Scheme in Kenya The operation will disk under a heavy volunteer crop of wheat in preparation for drilling. This land was disk plowed the first time in the 1967 season and this is the second time it has been plowed. The soil pulverizes very readily and reduces to fine dust if dry and overworked. The 14 independently sprung disks follow the rough ground contour and do an excellent job of breaking the land to 10 or 15 cm. The capacity of a 60 hp. tractor is greatly increased with this tool over the conventional 3 or 4 furrow disk plow. (AFR-99)

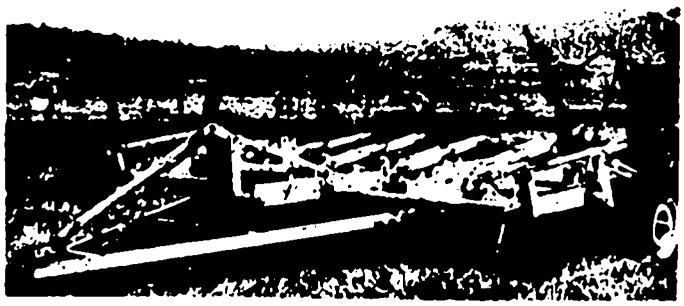

Figure 3.74 Large chisel plow (Australian) used in wheat production: Tanzania In the semi-arid region of northern Tanzania, the Northern Research Station of the Ministry of Agriculture, Forestry and Wildlife has shown that high yields can be obtained with minimum tillage. This special tillage tool leaves nearly all of the stubble and vegetation on top, conserving moisture and protecting the highly erosive soil from wind and water. A system of contour strip cropping is also employed so that only about 50 percent of the land is in crops at any one time. (AFR-508)

f) Chisel Plows There has been marked interest in chisel plows for the arid and semi-arid regions where moisture conservation and wind erosion are critical. For trash mulching to leave most of the vegetation on top, the chisel plow performs very well. (Figure 3.74.) McCartney at the Western Kilimanjaro Research Station in Tanzania got excellent results with this method and strip tillage.[198] 40 to 60 percent of the land area is plowed each half-year and planted in wheat. This is done in contour strips, so that at any time half the land is under cultivation and the rest under a heavy stubble mulch. Results show increased wheat yields, better soil tilth, higher moisture retention, and protection from wind and water erosion.

This system compares favorably with the action of the indigenous plow except that it can be done more quickly and effectively with tractor power. Deeper penetration is secured and only one operation is required with the larger tools. Seeding is done by dropping the seed into the mulch and harrowing it in with a long rigid-tooth flexible harrow pulled directly behind the simplified seed drill without furrow openers.

g) Bornu Complete Tillage Machine This special tool was developed by Shambaugh at Maiduguri, Bornu Province, northeastern Nigeria after five years of adaptive research and field trials. (Figure 3.75.) It is a simple, basic and rugged machine to be used with a standard-size, four-wheel, utility-type tractor with Category II three-point hitch for full mechanized farming in developing countries. It is capable of providing almost any degree of mechanized assistance to hand- and animal-powered farmers through a contract-hire service or when operated by a farmer-contractor for his neighbors. A complete description, including assembly instructions and parts is given in a special report.[199]

Shambaugh says the Bornu Complete Tillage Machine, with the attachments described, can handle all tillage operations from initial breaking through the weeding of row crops up to 1.5 m. tall. He reports that the cost of the complete machine equipped to do primary tillage, weeding and fertilizing is $1,003.00 for standard implement parts, plus about $12.00 for locally-made parts, for a total cost of $1,015.00 including freight to Nigeria.

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[198] J. McCartney, Agricultural Research Officer, Tengeru Northern Research Station, Tanzania, Personal Communication, October, 1968.

[199] Shambaugh, *Bornu Complete Tillage Machine*, p. 18.

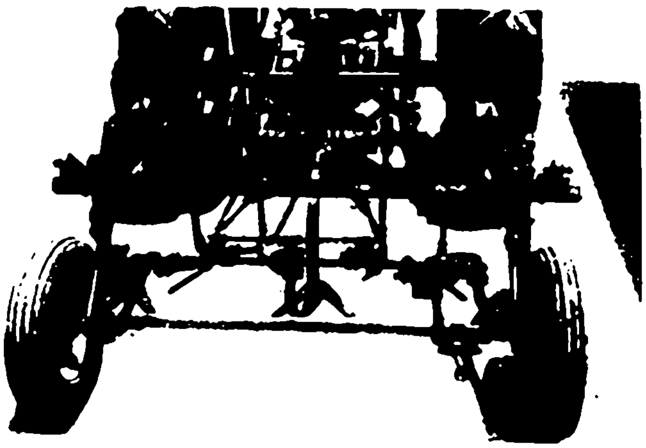

Figure 3.75 Bornu Complete Tillage Machine (USAID/Nigeria) Developed by Shambaugh in northeastern Nigeria, this multi-purpose tractor-powered toolbar is assembled from standard manufactured parts. It can be used to assist the hand- and animal-powered farmer as well as doing the complete job of mechanically tilling, planting, cultivating and harvesting groundnuts. Only a few special attachments and mounting brackets are needed to adapt the tools to a standard-model farm tractor. With two row coverage its average capacity is approximately 1 to 1.5 ha./hr. The overall cost for the toolbar and attachments for tillage, weeding and fertilizing is about $1,015 including freight to Nigeria (1968 prices). (Photo courtesy of T.J. Shambaugh, Jr., USAID/Nigeria, Industrial Development Center, Zaria, Northern Nigeria, 1969)

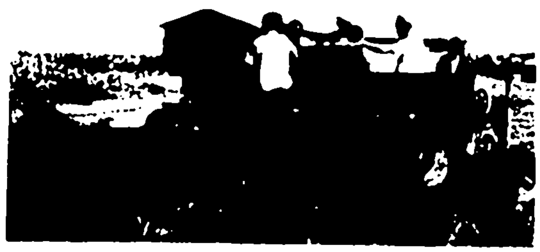

Figure 3.76 Seed-box attachment for one-way wide-level disk harrow A few seeder attachments are found in northwest Ethiopia but none are currently being used in the Setit-Humera area. The farmers say they waste too much seed, are not accurate enough to give good stands or too costly because they need so many units to cover their large areas in a short time. As a result cotton, grain sorghum, and sesame are all broadcast by hand and weeded with a hand hoe since mechanical cultivation is not possible. After two or three years of cropping most farmers complain of greatly reduced yields even though the soils are fertile. Uncontrolled weeds appear to be the major cause. Farmers in Sudan are reported to be successfully using these seeders for sorghum and sesame production. (AFR-14)

3) Planting and Seeding Tools and Practices

a) Seed-box Attachments for One-way, Wide-level Disk Harrows Although a number of Ethiopian farmers have these units they are not being used for sowing sorghum, sesame or cotton. (Figure 3.76.) One large farmer with three units said he would have to have a minimum of nine more to get his seeding done on time. He prefers to use 30 to 40 men broadcasting by hand and then covering the seed with the wide-level, one-way disk harrow. Similar units are used for seeding, however, in other countries such as Sudan.

b) Four- and Six-row Toolbar Planters The Tendaho Plantations in Ethiopia are able to plant 20 to 25 hectares per 12-hour day with a four-row planter on 90 cm. spacings. No fertilizing or spraying is done in this operation. Converting the planters to six-row units by extending the toolbar and adding half of another four-row planter, they were able to increase the effective capacity to 35 hectares per 12-hour day.[200] (Figure 3.77.)

Figure 3.77 Six-row planter made from modified four-row planter in Ethiopia Where fields are large and long, level, free of obstructions, wet spots and other hazards, a marked increase in capacity and efficiency can be achieved by skilled operators with larger equipment. Tendaho Plantations achieved a 200 to 300 percent increase in field capacity with four-row planters from 1966 to 1968. In 1968 the introduction of the six-row machine in place of the four-row further increased output 50 to 75 percent. While part of the results were obtained with better physical equipment and facilities, much of the credit goes to machinery operators who knew their jobs, properly maintained equipment, and kept idle time to a minimum. (AFR-492)

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[200] Michael Harley, Farm Equipment Supervisor, Tendaho Plantations Share Company, Addis Ababa, Ethiopia, Personal Communication, September, 1968.

c) Hoe Drills for Rough Land Wheat-seeding In preparing virgin land and reclaimed land in the Masai Wheat Scheme in Kenya, Downing reported that good plant stands were impossible to get using the disk plow and standard seed drill. The disk drill rode over the top of the rough surface, and the seed germinated prematurely or seedlings failed to survive. The yield was reduced and wind erosion encouraged. The use of an independently-sprung hoe drill with furrow openers gave much better stands and placed the seeds at the desired depth. Because of the heavy trash mulch, it was necessary to use a drill with staggered shanks to prevent blockages.

The Australian Conner-Shea hoe-drill did an excellent job according to Downing. He says:

> The Conner-Shea 'tine cultivator-combine' is a four-rank, 18 cm. spaced, 18 hole drill. Each tine is independently spring-mounted and the complete unit costs $1,075.00 on rubber. It has a fluted-wheel seeder with a fertilizer box. Its worst fault is the small seed box holding only 136 kg. of seed. The operator must also grease the bearings on the disks. It will clear and pass large amounts of trash and works well in newly prepared land.[201]

d) Bornu Complete Tillage Machine for Row-marking, Planting and Fertilizing

> The machine is used for: ripping the row area where the fertilizer and seed are to be placed for better seedbed preparation and to attract more of the first moisture to this deeper tilled area; application of starter fertilizer to the side and slightly deeper than the seed to be hand planted; weed control just ahead of planting; marking two rows for hand planting at exact spacing. The farmer must carefully plant exactly in the marks left by the rear 51 cm. wheatland sweeps in order that the two marked rows will be exactly 90 cm. apart which is essential for two-row mechanical cultivation. The farmer will then thin and transplant the crop and do as much hand weeding as he can. When the labor and economic situation permits, two 25-B John Deere or similar unit planters may be attached to the rear toolbar instead of the two 51 cm. wheatland sweeps and the planting and fertilizing done by machine. The capacity of the machine for this work should be approximately 1.2 hectares per hour.[202]

4) Weeding Tools and Practices

a) Row-Crop Cultivators In most parts of equatorial Africa, weeding is still done by hand even where land is prepared by tractors. Most tractor-hire services do not offer a planting or cultivating service, nor do hand farmers desire it at this stage of development.

With their limited resources, small farmers cannot afford to hire extra

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[201] Downing, *op. cit.*

[202] Shambaugh, *Bornu Complete Tillage Machine*, p. 4.

help except for tillage. But, if crops are *not* planted in straight parallel rows, it is not possible to cultivate them mechanically or economically. *Cultivator shovels cannot be worked close enough to the plants for effective weeding unless the rows are very carefully marked with a furrow-marking device and planted precisely by hand.* (Figure 3.78.) Where the tractor-hire services are doing work for large farms and settlements which are equipped with row planters, some row crop weeding is done.

b) Toolbar Cultivators Most American and European mid-mounted cultivators for row crops are too complex and costly for African conditions. Plantations and large commercial farms raising row crops generally have favored a rear-mounted toolbar cultivator that can be assembled from standard components, which is simple, rugged and relatively inexpensive. With good tillage practices and weed control before planting, the job of inter-row weeding is minimized. The Tendaho Plantations made *such units which were effective and gave very good weed control when the cultivations were timely and well managed.* (Figure 3.79.)

c) Bornu Complete Tillage Machine for Row-Crop Cultivation[203] The machine is equipped for multiple-row weeding of all crops from emergence to 1.5 meters tall. Two rows can be cultivated at the same time, but they must be equally spaced. On sandy soils with grassy weeds, 1/2 cm. steel rods 23 cm. long and 5 cm. apart, welded on the under side of the cultivator shovels, assist in throwing the weeds out of the soil. Washers placed between the top of the sweeps and the standards give more pitch to the sweeps to increase throw. These suggestions, plus a speed of 8 km. per hour result in satisfactory weeding.

Alternate rows are weeded to make it easier to turn at the ends. Depending on the accuracy of the row spacing and skill of the operator, the front round-turn knives may be set to weed closer to the plants. For later cultivation of all crops except groundnuts that need more dirt near the plants, the round-turn knives can be replaced with half wheatland sweeps. For additional earthing up, disk-hillers or lister-bottoms can be used at the last cultivation.

The capacity of the machine is approximately 1.4 hectares per hour. The Bornu Tillage Machine also may be equipped to add fertilizer to the growing crop while cultivating.

The Bornu Complete Tillage Machine was assembled from standard U.S. farm machinery parts with the exception of a few simple locally made attachment parts.[204] It consists of a double 198 cm. toolbar with various

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[203] *Ibid.*, p. 5.

[204] *Ibid.*, pp. 3-4.

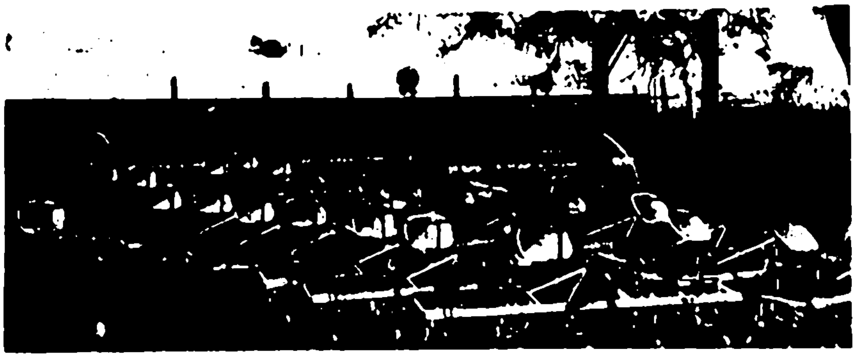

Figure 3.78 Tractor mounted 3-point hitch riding cultivators (Czecho-slovakian) seen in Ghana The selection of agricultural equipment for use in a developing country must be compatible with the crops, stage of agricultural development and needs of the farmer. These manually operated tractor-powered cultivators have never been used in western Africa. (AFR-548)

Figure 3.79 Simple tractor toolbar cultivators (U.S. and British) This implement can be locally assembled from standard parts. Simple, sturdy, inexpensive and effective tools are needed in developing countries. Land is often not properly cleared, destumped and drained and tools receive very hard use. Multiple purpose tools, simple and rugged, are needed to work and bring into production newly cleared or reclaimed land with minimum expense, adjustment and breakage of the machinery. High clearance and trip-action working parts help in avoiding damage. (AFR-499)

attachments for primary tillage, weeding and fertilizer application. It can be used either as a 2.14 meter wide ripper, field cultivator or a two-row weeding machine with a fertilizer side dressing attachment. Many other attachments such as rotary row weeders, groundnut lifters, and planters can be attached to the basic toolbar frame as the need arises.

Primary tillage or ripping should immediately follow crop harvest before the soil becomes too hard. It leaves large clods to absorb as much of the early rains as possible. If difficulty is encountered in getting proper penetration, the chisel points have probably worn off and need replacement. A set of right and left twisted shovels may be used instead of the double-pointed chisels for handling and covering more trash.

The Bornu Tillage Machine is equipped for complete weed control. Each of the blades of the sweep-type shovels overlaps 5 cm. and should run at a depth to cut off the weeds and at a speed fast enough to shake all of the dirt from the roots of the plants. In extremely heavy weeds, narrow sections of peg-tooth harrow can be pulled behind the cultivator between the rows.

The cultivator should be used often enough to keep the weeds under 15 cm. tall and to keep vine-like plants under 30 cm. long. If vines are the main problem, disks and straight standards must be substituted for the shovels and curved standards. This machine should be operated at 8 to 9.5 kilometers per hour to provide proper soil turbulence, giving it a weeding capacity of approximately 1.6 hectares per hour.

5) Harvesting and Threshing Machines and Practices

a) Large Stationary Thresher A number of large, old, Hungarian and Italian threshers are used in south central Ethiopia. They are pulled around from farm to farm and used to thresh wheat and barley for the larger farmers. The service is offered as part of the contract-hire work done by the Kulumsa Seed Multiplication Farm operated by the Swedish CADU project on agricultural development.

b) Sesame Harvester A new machine has been developed by the Laverda Company of Italy to cut and bundle sesame and reportedly it can do the work of 100 men. It was exhibited at the Asmara Exposition in February, 1969, and is being tried for the first time this year at Setit-Humera. No information is available on sales, capacity, cost or specifications of the harvester. Cutting sesame was mentioned as the main problem of Setit-Humera farmers in 1968. (Figure 3.80.)

c) Self-propelled Combine The Grinaldi Italian farmers south of Tesseni in northwest Ethiopia are using combines for harvesting and threshing their grain. They recently purchased a Massey-Ferguson 410 with 3.67 meter

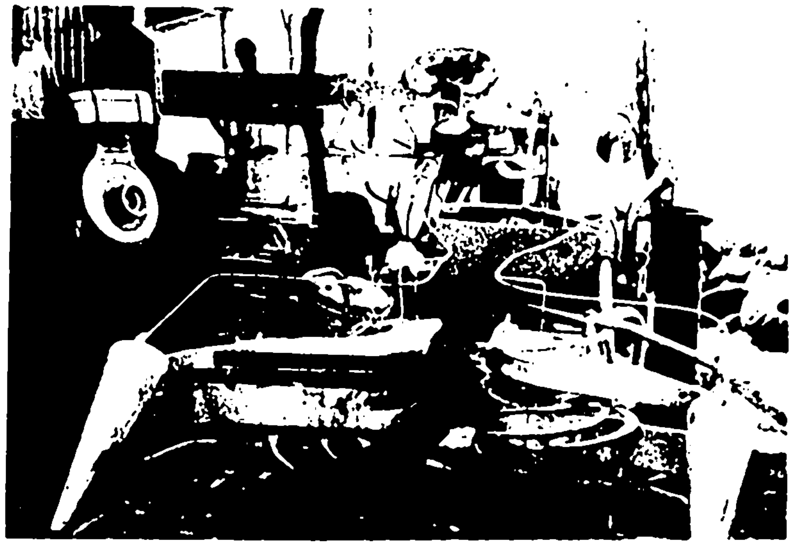

Figure 3.80 A new Italian self-propelled sesame harvester seen in Ethiopia Early in 1968 the Setit-Humera farmers stated a major problem was getting sesame harvested before it shattered. While hand labor can easily harvest and bundle sesame, the time period (of 2 weeks) after ripening is very short. Unmet demands for higher wages left many farmers holding empty bags in 1967. Introduced at the Asmara Exposition in 1969, this harvester was first seen in northwest Ethiopia in February, 1969. It can cut and tie an estimated one-half hectare per hour at a speed of 4 kph. This is an example of a specific tool which might be designed by a national research organization. (AFR-447)

cut and grain tank. Fields are 2 km. long so little time is wasted in turning. The speed of operation was very fast on dwarf sorghum, averaging 13 kph. This was possible on the smooth fields with uniform straight stalks which could be cut close to the head. Downing said an automatic header-control is very desirable because the operator manually cannot keep the combine level on uneven hilly fields.[205]

In Kenya all wheat is harvested with combines. Wheat is primarily grown by non-African farmers and by the government on the Masai Wheat Scheme. Because of the wide difference in elevations (1800 to 2800 meters) and the extended rainy season, the land can be prepared and planted over several months. This permits contractors to start combining in the low elevations about October and continue until February at the high elevation. (Figure 3.81.)

[205] Downing, *op. cit.*

Figure 3.81 German combine Claas combining Masai Wheat northeast of Narok in Kenya This first crop of wheat on virgin land averaged from 2440 to 3770 kgs./hectare. Even so, the combine was underloaded and passing quite a lot of grain over the sieves. A lower cut or a wider cutter head would have helped to use the machine to capacity to improve its operation. (AFR-553)

Some Africans are buying combines and out of eight sold by J.I. Case Company in Kenya, two were purchased by Africans. Other companies (primarily John Deere, Massey-Ferguson and Claas [German]) say that 10 to 20 percent of their combine sales are to Africans. The average custom-operator with a single unit is combining 600 to 800 hectares in a season while a few operators are combining up to 1,600 hectares per season. With trained operators there have been few mechanical problems.

In Ghana most of the combines are Russian or Czechoslovakian. While the tractor-hire service has several Czechoslovakian 780 Special machines, only a few are operational. Tractors are used primarily for upland and flood-irrigated lowland rice production. The Russian machines are track-type units of cumbersome design used mainly at the Afife State Farm in southeast Ghana. (Figure 3.82.)

The Czechoslovakian units are concentrated in the northern and upper regions and operated by the Mechanization and Transport Division of the Ministry of Agriculture. One district pool at Bawku with two combines (one serviceable) reported that 53 hectares were harvested in the 1967-68 season. The farmers did not like these combines because too much grain was cracked. The heavy wheel-mounted units could not be used until the fields dried off

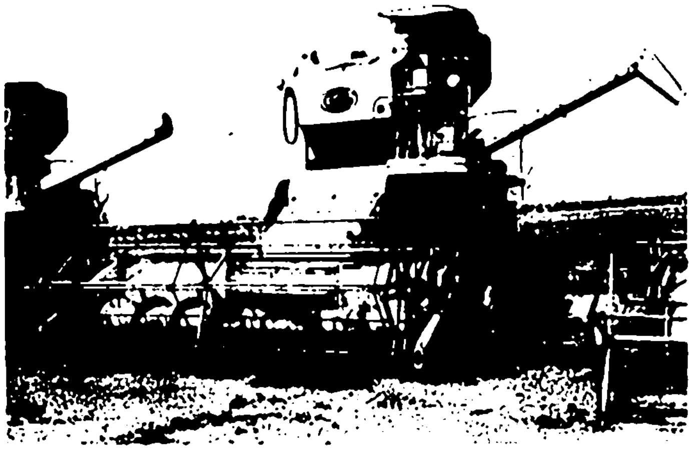

Figure 3.82 A Russian CKR-3 rice combine on crawler tracks The valley in which the farm is located near Afife, Ghana is flat and the present 800 hectares of the farm could be expanded to 1,600 hectares. Private farmers are now gradually taking over responsibility for rice production. (AFR-172)

Figure 3.83 Belt-driven sheller (United States) processing maize in northern Ghana Very little custom or farm processing is done in Equatorial Africa. A few state farms, research institutes, universities, mechanization schools and experimental stations do their own processing plus some occasional work for others. This equipment was seen at the Navrongo Farm Mechanization Training School near Bolgatonga. Most installations involve considerable manual operation. (AFR-507)

and by this time shattering losses were high.

d) Maize Pickers and Shellers Most small African farmers pick and husk maize ears by hand. Large farms, agricultural schools or cooperative farms with engine-powered shellers may do some custom work. Occasionally a tractor-hire service unit, a mechanization school, or settlement farm may do contract hire work. (Figure 3.83.) The large commercial farms in East Africa have gone straight from hand-picking to combine-sheller operation, skipping the intermediate stage using the mechanical ear-picker common in the U.S. Advanced technology is being applied directly by large European farmers or plantations.

6) Output, Power, Capacity and Labor Required for Large Tractors and Equipment

Capacities vary greatly for tillage operations depending upon the implement design, power-unit, soil-type and conditions, moisture content, length of fallow period, previous crop, skill of operation and proper adjustment. For a general idea of output and times see Table III. 21. A few cases are presented here for African conditions.

a) One-way wide-level Disk Harrows These units are used exclusively in Ethiopia in the Setit-Humera area on dry vertisol soil with scanty vegetation. Power is furnished by the Massey-Ferguson 165 in second gear at 9.0 to 9.7 kph. The output of a one-way, wide-level, 24 disk harrow cutting about 3.5 meters was 2.5 hectares per hour or 20 hectares per 8-hour day. In three months one tractor and harrow can cover 600 hectares of cleared land twice or about 1,200 hectares once. Ideally, a farmer should be able to do 1,600 hectares in 80 working days but practical limitations, break-downs and operator deficiencies reduce this to 70 to 75 percent capacity. With other tractors, such as the Italian Same, with a disking speed of only 6.0 to 8.0 kph, the coverage was substantially less, or 1.5 to 2 hectares per hour or 12 to 16 hectares per day.

The Tendaho Plantations Share Company in Ethiopia reported covering 30 to 35 hectares in a 10-hour day with the Massey-Ferguson wide level, one-way, 24-disk harrow. Remarkable improvement was shown in three years, from 10 hectares up to 30 to 35 hectares per day due to better management, improved land preparation and increased operator skills. For a complete list of field operations and machine capacities on a well-managed plantation see Table IV. 8.

b) Mounted Disk Plows On Tendaho Plantations, with a four-furrow disk plow four to five hectares per 10-hour day with the Massey-Ferguson 165 tractor have been averaged. In contrast, with a five-furrow moldboard

semi-mounted plow pulled by a Massey-Ferguson 175 tractor six to eight hectares per 10-hour day have been averaged.

c) Bornu Complete Tillage Machine Shambaugh reports that the average capacity for all operations is 1.2 hectares per hour or 9.7 hectares per 8-hour day.[206]

For primary tillage or ripping, the capacity varies considerably depending upon the working depth and power requirements but should range between 1.0 to 1.6 hectares per hour. For planting, the capacity is about 1.2 hectares per hour. As a field cultivator, the capacity is a little higher or 1.6 hectares per hour. For weeding in the row, the capacity is approximately 1.4 hectares per hour.

d) Combining Little information was available on actual hourly or daily capacities for harvesting operations. Grinaldi in northwest Ethiopia reported that with a Massey-Ferguson 410, 3.6 meter cut and traveling at 13 kph. they were able to harvest 15 hectares in an eight-hour day. Fields were very long (two kilometers), and crop and soil conditions were ideal; Grinaldi was maintaining and operating the machines.[207]

7) Skill and Management Required with Large Tractors and Equipment

a) Weed Control under Sparse Rainfall Conditions In northern Ethiopia the system of killing weeds begins by leaving the ground fallow for one season. After the first 20 mm. of rain, the land is disked 7 to 8-cm. deep and the weeds allowed to germinate for 7 to 10 days. Then the field is disked again. After three to five diskings, the weeds in the worst fields are largely controlled before seeding.

b) Weed Control on Flood-irrigated Land Basic land preparation techniques on Tendaho Plantations work very well for pre-planting weed control. Rapid disk plowing breaks up roots about 15 to 18 cm. deep. Field work standards are high with good plowing, even rows and level fields. After much experimentation, Tendaho has evolved the following program for weed control using flood irrigation:

1. Use a slash or rotary chopper to pulverize cotton stalks.
2. Plow straight under if not too dense, otherwise rake and burn excess crop residue.
3. Leave the land open without a cover crop to dry out the soil.
4. Disk when weed growth appears in April after the first rains.

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[206]Shambaugh, *Bornu Complete Tillage Machine*, pp. 2-8.

[207]S. Grinaldi, Farmer, Tessini, northwest Ethiopia, Personal Communication, March, 1968.

5. Perform no further cultivation until the rains come, but land leveling may be done if needed.

6. Apply the first irrigation about June 10.

7. Plant immediately after irrigation six to 6.5 cm. deep with seed at 30-40 kg./ha.

8. Cultivate after the first weeds appear at 11 to 13 kg. per hour.

9. Irrigate a second time 40 days after the initial irrigation.

10. Inter-row cultivate with tractors, 15 to 20 days later.

11. Irrigate the third time 73 days after first irrigation (some areas receive a fourth and fifth irrigation).

12. Make another inter-row cultivation if needed, or desirable.
(Table II. 42.)

c) Weed Control by Inexperienced Farmers The newly mechanized farmer often only plows or disks once before planting. Many have severe weed problems due to failure to adequately control weeds *prior* to planting. Disking is not needed to loosen the vertisols because they crack and tend to be self-mulching, but it is needed to kill weeds and to prepare a continuous even base for seeding.

The more experienced farmers disk twice, once after the first 30 to 40 mm. of rain have sprouted the first seeds and a second time after 7 to 10 days to fill in the cracks and to kill the second growth of small weeds. After another 7 to 10 days, they plant and disk immediately to cover the seed so that it is not eaten by the numerous weaver birds. The second disking must be completed before planting begins as the harrows are used for covering immediately behind the hand sowers.

d) Sowing with Box Seeders on One-way Wide-angle Disk Harrows The Grinaldi Partners, south of Tessini in northwest Ethiopia, are using regular Massey-Ferguson seeders on one-way disks which other Setit-Humera farmers claim can not be used.[208] However, to sow sesame, they mix seed with cow manure to add bulk, get the right seed rate, and act as starter fertilizer. No fertilizer is used on dura or cotton and seeds are allowed to drop ahead of the disks; drag chains are not used for covering.

Plant population appeared low where fluted-wheel seed drills were used.

e) Using the Bornu Complete Tillage Machine Since this machine will not handle long pieces of trash, the following procedure is suggested by Shambaugh.[209] If the stalks are not to be used, remove the guinea corn

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[208]Grinaldi, *op. cit.*

[209]Shambaugh, *Bornu Complete Tillage Machine*, p. 2.

and millet heads and leave the stalks standing. If a rotary mower is available shred the trash into small pieces. Otherwise, convert the tillage machine into a sulky rake by putting all the flat curved steel standards on the rear toolbar and rake the trash into wind rows for removal or burning, then proceed with normal tillage operations.

f) Using Machine Capacity to Insure Early Planting Zack Tyson, agricultural engineer with the USAID Mission in Sudan for eight years, conducted tillage and sowing experiments with wheat.[210] He reported the best preparation and planting yields were attained with a wide-level and offset disk used with a planter rather than with a drill or disk-harrow seeder on a wide-level disk. Increased plant population gave higher yields, and averaged over 2000 kg. per hectare for wheat, using 71 cm. row spacing. However, the most important factor was the planting date, and the highest yields were always associated with early and timely planting. The ground was disked once before planting for weed control.

TABLE III. 24 EFFECT OF PLANTING DATE ON WHEAT YIELDS: SUDAN 1963-66

Planting Date	Average Yields kg./h.a.
Before July 15	2440
Between July 20 and August 10	1825
Between August 15 and August 25	812

Source: Zack Tyson, *op. cit.*

8) Costs of Agricultural Operations of Wheel Tractors

a) CADU Machinery Pool Services[211] After two years of operation, CADU believes the services of Kulumsa Farm to farmers in the surrounding area (mainly threshing and plowing) should continue on an expanding scale. The extension agents act as agents for the machinery services from Kulumsa. The capacity of the machinery pool during 1968/69 is estimated at 3,760 tractor hours and 125 combine hours. Some changes have been made in service charges because in principle, the services should be given at a cost price. No budget is allocated for losses and no profit is anticipated. To encourage

[210] Zack Tyson, Currently USAID Agricultural Engineer in Lagos, Nigeria: formerly with USAID Mission in Khartoum, Sudan, Personal Communication, April, 1967.

[211] Chilalo Agricultural Development Unit, *Plan of Work and Budget, 1968/69*, (mimeographed) (Addis Ababa: Swedish International Development Agency, 1969), p. 156.

the customers to fully utilize the capacity of the machines by organizing the work, the charge is set *per hour* instead of per quintal or hectare. This means that more farmers can be helped each season and wasted time is considerably less.[212] Hire charges are based on the following principles and conditions:

1. Combining: The previous charge was $1.00 per quintal plus motor fuel and allowance for the operator. The charge under CADU management is $12.00 per hour, including costs for fuel and operator. Under normal conditions, it is possible to thresh 10 to 12, and even 15 quintals per hour, which means that the new charge is lower than the previous one.

2. Threshing with Station ry Thresher: The previous charge was $0.40 per quintal, plus tractor fuel and allowance for the operator. The new charge is $6.00 per hour and when 12 quintals or more are threshed per hour, it will cost the customer less. Up to 22 quintals per hour have been obtained but with the stationary thresher, the output is entirely dependent upon the work organization. (Figure 3.84.)

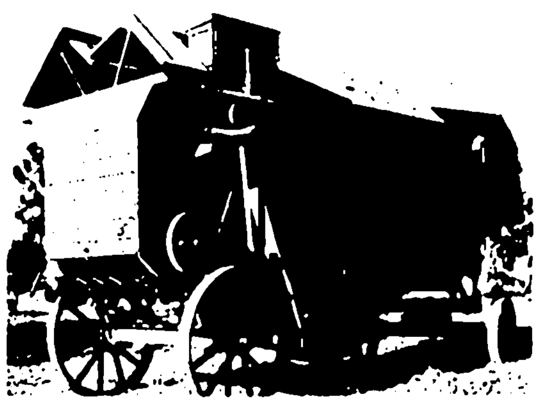

Figure 3.84 Stationary thresher used for custom threshing in Ethiopia
A Hungarian made thresher currently used by the Chilalo Agricultural Development Unit on the Kulumsa Seed Farm. This farm, used for seed multiplication, also operates a limited threshing service for area farmers. The demand is increasing yearly and some combine harvesting for larger farmers is done. The traditional threshing method used by most farmers in this region is animal-trampling. (AFR-49)

[212]Chilalo Agricultural Development Unit, *Plan of Work and Budget 1968/69*, p. 55.

3. Plowing and Harrowing: The previous charge was $7.20 per hectare, plus fuel and allowance for the tractor operator, which gives an actual cost of about $10.00 per hectare. The new charge is $4.80 per hour including all costs and under normal conditions, three to four hectares per day can be plowed, making the new charge about the same as the old.

4. Other Services: Additional services, such as transportation are calculated and quoted to the customer in advance. The basic charge for a tractor and wagon, including fuel and operator, is $3.20 per hour.

b) Ghana Tractor-hire Service The Mechanization and Transport Division of the Ministry of Agriculture operates a Tractor-hire Service for farmers, settlements, state farms and other groups. Its standard farm-size power unit is the Zetor Super 50 hp. four-wheel utility tractor, made in Czechoslovakia and delivered to Accra for $2,790.00. Costs of tractor operation (Table I. 7) have been based on an estimated life of five years or 8,000 hours (6,000 would be very good). While all of the tractors are equipped with hour meters few function so that actual hours of operation are difficult to judge. Nevertheless, the highest recorded hours of any tractor observed (after four to five years of use) was less than 2,000 hours. Considering the kind of use, the frequency of breakdown, the difficulties in securing repairs, it is doubtful that any tractor has done 4,000 hours of productive work. If this is true, the depreciation rate should be double that shown in Column 4 Table I. 7. Note that no interest on investment, taxes, housing and insurance has been considered. (Figure 3.85.)

Figure 3.85 Tractor-hire Scheme, Ghana Tractors facilitate the application of high concentrations of power to agricultural production. Less than one percent of farmers in Equatorial Africa are ready to operate tractors. Government Tractor-hire Schemes, as shown here in central northern Ghana, are one-half a step toward full tractorization. Private ownership of tractors and private tractor custom services should also be encouraged where there are operators who can manage such services economically. (AFR-527)

In Table III. 25 the cost of various crop production operations represent the use of a tractor on a large Ghana farm or plantation with adequate size fields, properly cleared, minimum road movement, and regular supervised maintenance facilities and predictable utilization.

The costs of operation will be substantially higher for a hire service catering to scattered farmers under typical African rural conditions with small, irregular shaped fields, hidden obstalces, scattered locations, difficult access, seasonal or poor road conditions. To the regular charge must be added a movement or service charge to compensate for reduced efficiency and increased outfield expense. The sixth column of Table III. 25 includes a 50 percent surcharge to offset the unsatisfactory conditions under which the tractor-hire services must operate, including movement of fuel and supplies to villages. The last column shows the amount of subsidy the government must absorb if it charges farmers according to those fixed by the United Ghana Farmers Cooperative Council (UGFCC).

For more economical operation, tractor-hire services should not work fields smaller than two hectares and the land should be in rectangular blocks. New opportunities should also be sought to productively employ tractors and operators after the seasonal agricultural work is completed. For example, tractors could be used for contract hauling, building and repairing roads, operating grain grinders and feed mills, powering irrigation pumps, mowing grass, cutting brush, light earth work, ridging and similar jobs which do not require expensive attachments but which greatly expand the scope of utilization.

c) Nigerian Tractor Costs of Operation It was agreed that wheel tractor costs would include:[213]

1. Fuel consumption;

2. Fixed ownership costs, including straight-line depreciation to nil scrap value;

3. Life estimated at 5000 hours in five years;

4. License and insurance costs;

5. Interest on capital and housing is *not* to be included;

6. Cost of tractor should be cost to a farmer, not a discounted government price;

7. Repairs averaged at 50 percent over five years, or 10 percent of first cost per year;

8. Wages would be charged at actual rates of $1.75 per day with no allowance for idle time.

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[213] Second Meeting of Agricultural Engineers, Institute for Agricultural Research, Ahmadu Bello University and Ministry of Agriculture, Kaduna, Northern Nigeria, November, 1964.

TABLE III. 25 COSTS PER HECTARE OF MACHINERY OPERATIONS FOR LARGE FARMS AND AS A SERVICE TO SMALL FARMERS: GHANA 1968[a]

Operation	Tractor cost	Implement cost	Operation cost	Average Rate of operation	Total Cost	50 percent surcharge for extension work[b]	Government Fixed Charge	Subsidy percent[c]
	$/hr.	$/hr.	$/hr.	hr./ha.	$/ha.	$/ha.	$/ha.	
Plowing, disk	1.71	0.30	2.01	5.6	11.26	16.88	9.88	42
Plowing, moldboard	1.71	n.a.	-	n.a.	-	-	-	-
Harrowing or Disking (offset)	1.71	.30	2.01	3.1	6.23	9.35	5.40	42
Ridging, initial	1.71	.15	1.86	3.7	6.88	10.32	9.88	5
Reshaping ridges	1.71	.15	1.86	2.5	4.65	6.98	5.40	23
Planting with fertilizer (four-row)	1.71	.90	2.61	3.7	9.66	14.49	12.33	15
Drilling grain (10-row)	1.71	.90	2.61	3.7	9.66	14.49	12.33	15
Slashing, rotary	1.71	.30	2.01	3.7	7.44	11.16	9.88	12
Hoeing, steerage	1.71	.30	2.01	2.5	5.03	7.55	5.40	29
Cultivation, inter-row	1.71	.15	1.86	2.5	4.65	6.98	5.40	23
Shelling maize	1.71	.85	2.56	-	-	-	-	-

[a] See Table I. 7 Column 4 for basic tractor cost per hour. Data adapted from H. Kumar, *Cost of Tractor Operation*, Ref. No. Des/T10/SF4/V2/19 (Accra: Mechanization and Transport Division, Ministry of Agriculture, August, 1968), p. 2.

[b] Extension work is the tractor-hire service performed for small farmers arranged through the Agricultural Extension Service at rates set by the United Ghana Farmers Cooperative Council.

[c] $\frac{\text{(Total cost) - (Charge to farmer)}}{\text{Total cost}}$ = Percent subsidy

It was agreed to take 50 percent of life of implements shown in American and British standards. Repairs were set at 100 percent of first costs over the same life.

9) Costs of Agricultural Operations of Crawler Tractors

a) Ghana Land-clearing Costs Land clearing is one of the principal jobs for which crawler tractors are especially suited. The Ghana Ministry of Agriculture has three models and sizes of Yugoslavian tractors. The Bratslvo BNT-60, 60 hp. crawler, is used primarily for heavy plowing, root raking, light dozing and brush clearing. The Oktobar TG-90, 90 hp. model, was selected for medium to heavy clearing and common earth moving and excavating. The model TG-160, 160 hp. unit, used only for very heavy clearing or large-scale projects. (Figure 3.86.)

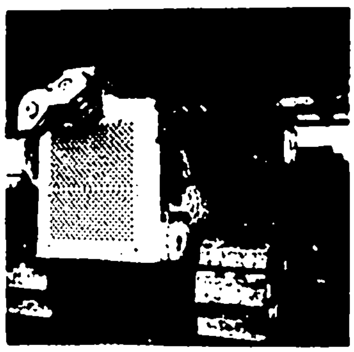

Figure 3.86 Crawler tractor (Yugoslavian) used in Ghana for land clearing The tractor shown, a TG-90 (90 hp.) is one of three track-type tractors purchased from eastern Europe. Now operated by the Mechanization and Transport Division of the Ministry of Agriculture, crawlers are assigned the task of developing agricultural land of high potential. The other most common crawler is the BNT-60 (60 hp.) illustrated in Figure 2.26 which is used for light dozing, root raking and heavy disking and plowing. Only a few TG-160 or 160 hp. Oktobar tractors are used for heavy clearing. (AFR-542)

Kumar calculates the hourly cost of operation of a 90 hp. crawler at about $9.00, as shown in Table III. 26. Depreciation is based on a 10,000 hour service life which is unlikely to be reached. Based on the performance of these tractors so far in Ghana, a useful life of 5,000 or perhaps 7,500 hours under excellent management would be above average. If this were the case, the total cost per hour would be increased by adding another 50 to 100 percent of the depreciation cost equal to $1.27 to $2.54 per hour for a total cost of $10.30 to $11.57 per hour of operation. The delivered cost of the TG-90 tractor to Ghana was approximately $25,450.

TABLE III. 26 HOURLY COST OF OPERATION OF YUGOSLAVIAN TG-90 CRAWLER TRACTOR: GHANA 1968[a]

Item	Basis	Cost
		$/hr.
Depreciation	Price, $25,450; life 10,000 hours	2.54
Repairs and spare parts	100 percent of depreciation	2.54
Operator and helper	$2.42 for a seven-hour day	0.35
Fuel (diesel)	17 liters/hour @ $0.38/gal.	1.73
Oil filters, oil	25 percent of fuel cost	0.43
Grease		0.10
Subtotal Cost		7.69
Overhead: administrative, supervision, and logistics	@ 15 percent	1.15
Total net operating cost per hour		8.84

[a]Kumar, *op. cit.*, p. 3.

Clearing costs with heavy machinery are expensive as indicated in Table III. 27. With time limitations, or when large areas must be prepared for commercial projects, stumps and large trees can be removed more quickly and more easily with large tractors. Land clearing is essentially a long-term capital investment. To encourage proper clearing, Kumar believes that charges should be payable over a period of five years. Also charges for units should be based on a time charge rather than an area charge, which is very difficult to judge under widely differing conditions. Generally, governments provide substantial help to land owners in meeting land-clearing costs.

TABLE III. 27 LAND-CLEARING COSTS PER HECTARE WITH TG-90 CRAWLER: SOUTHERN GHANA 1968[a]

Type of Vegetation	Avg. hrs. to clear one ha.	Cost per tractor	Cost	Add 50% service charge	Present Ghana MOA charge	Subsidy[b]
		$/hr.	$/ha.	$	$/ha.	%
Bush	12.3	8.84	109.42	164.13	63.25	62
Savannah woodland	17.3	8.84	153.23	229.84	97.30	58
Coastal thicket	37.1	8.84	328.55	492.82	194.80	61
Secondary forest	44.5	8.84	394.36	591.54	271.00	54
Virgin forest	69.2	8.84	613.39	920.10	424.00	54

[a]Kumar, *op. cit.*, p. 4.

[b]$\frac{\text{(Total cost) - (Charge to farmer)}}{\text{Total cost}}$ = Percent subsidy

b) Nigerian Crawler Track-type Tractors The following figures were accepted based on the Jeri Bowl rice operation:

1. Depreciation over 10,000
2. No insurance or road license
3. Repairs at 60 percent over 10,000 hours use
4. Implements, trailer plows and harrows should be charged at $0.42/hour.

c) Comparison of Hand- and Machine-clearing Costs When time permits, the farmer may be able to do his own clearing cheaper than it can be done by machine. However, it usually does not include complete removal of stumps and roots so that animal- or engine-powered equipment can be used efficiently and safely. In the humid tropics partially cleared land grows back so that it must be recleared periodically. The land is suitable only for hand-farming if the clearing is not complete. In Table III. 28 a comparison is made over a ten-year period showing the initial and accumulative cost of clearing by the two methods and preparing the land for planting each year.

The costs of clearing savannah woodland by crawler-tractor operation (method A) and hand (method B) have been compared. The tractor method illustrated appears cheaper to the farmer, the removal of stumps and roots would require considerably more hand labor than has been shown. The government tractor rates also are subsidized, so the actual cost including subsidies is considerably higher to society as a whole (*i.e.* to the government) than the costs of hand clearing. Governments usually consider land clearing as part of their responsibility, this subsidy is not unreasonable; the example shows that the total costs of the tractor operation are considerably higher (almost twice) the amount the farmer actually pays for this work to be done.

TABLE III. 28 COMPARISON OF TWO METHODS OF CLEARING AND PREPARING FOUR HECTARES LIGHT SECONDARY GROWTH FOR PLANTING: NEAR SAPAIMAN, SOUTHERN GHANA 1968[a]

Method A[b]: Clearing and Tilling with TG-90 Crawler Tractor

Year	Operation	Costs for 4 hectares: Subsidy excluded		Costs for 4 hectares: Subsidy included
		dollars		dollars
1	Clear, stump, root & remove low growth forest 3 to 5 meters high in one-time operation with TG-90 crawler & dozer at gov't hire-rate ($63.25/ha.)	253.00	($164.13/ha.)	656.52
	Assume 16 km. transport charge at $0.74/km.	11.84		11.84
	Plow & harrow with BNT-60 crawler & 2-way 41 cm. moldboard plow & tandem 3 meter disk harrow at gov't hire-rate ($15.28/ha.)	61.12	($26.23/ha.)	104.82
	Assume 16 km. transport charge at $0.74/km.	11.84		11.84
2 ↓ 10	Plow and harrow only for 9 years at gov't hire-rate ($15.28/ha.)	550.08	($26.23/ha.)	944.28
	Crawler transport cost ($11.83/yr.)	106.47		106.47
	Total cost for clearing and tillage:	994.35		1835.77

Method B[c]: Clearing and Tilling with Manual Labor

Year	Operation	Costs for 4 hectares
		dollars
1	Four men at $1.00/day each. Clear by cutting off brush and small trees with cutlass and axe, leave stumps & roots. To clear, weed & hoe 4 hectares takes 40 days for four men. Four men can clear one hectare in ten days: 4 men x 10 days = 40 man-days x $1.00/day = $40.00	160.00
2 ↓ 10	Clear regrowth and prepare land each year for 9 years ($40.00/ha.)	1440.00
		1600.00

[a]Average farm size 5.3 hectares and lease 10 years. Data by A. Klevor, farmer, and A.D. Sokah, Mechanical Superintendent, Mechanization and Transport Division, Ministry of Agriculture, Ghana, Greater Accra Region, Amasaman, Ghana.

[b]It takes about 12 days to clear 4 hectares with the TG-90 crawler and about five days to plow and harrow for a total of 17 days to get ready to plant. Weed control is more effective with inversion plowing and subsequent weeding should be faster and easier. In addition, earlier and more timely planting favors better plant growth and subsequent yields. Soils must be suited for mechanization, however, as some light forest soils are severely damaged or destroyed by continuous use of machinery and intensive cropping. The farmer also is dependent upon the tractor hire service coming when requested, and it may not come on time.

[c]Stumps and roots would prevent effective tillage to control weed growth. The 40-day delay in clearing also may be detrimental to yields if planting is delayed beyond optimum time. Farmers can, however, begin clearing and hoeing at any time their farm work schedule permits.

CHAPTER IV

ANALYSES OF PRESENT FARMING SYSTEMS

Introduction

The accelerated development of agriculture in Equatorial Africa cannot ignore the needs and the problems of the small farmer. The economic and technical development process must be adapted to the unique features of each tropical rural culture, and to geographical, agrarian and social environment. Farmers need more power, better tools, and the benefits of technology along with the support of state and national infrastructure. The development of a market economy is imperative to permit specialization and to provide the stimulus and the reward for the profitable disposal of increased production.

The hand-hoe farmer cultivates a maximum of 4 to 5 hectares. He has the greatest need but the least favorable possibilities for more adequate power. Hoe culture, therefore, must maximize other inputs which offer the best potential for increased production with the least demand for power. The first requirement is to select only the best soil for cultivation. Then, most effective use should be made of improved seeds and plants, fertilization, seed innoculation, plant protection, intensive weeding and thinning to create the best environment for plant growth. *Good management with timely operations in all these areas is an absolute prerequisite for success.*

The final subdivision of this chapter discusses an economic analysis of the farming systems and the associated social factors; the first three subdivisions are concerned with the engineering and technical aspects.

Hand-powered Agricultural Systems

Shifting Cultivation and Hand Farming

The effect of shifting cultivation on soils is discussed in Chapter I under bush fallow and soil management. Its effect on cultivation practices and crop systems is described by an FAO team survey of subsistence farming in West Africa.[1]

When no manures or fertilizers are used, shifting cultivation is a valid system. Recently cleared land is also free of weeds. The principal defect is low yield per unit of labor. All tillage is done by hand, with hand transport of products from field to village because:

1. Fallows are bush and not grass fallows; stumps are not removed because it is too costly for land to be later abandoned.

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[1] J. Papadakis, *Crop Ecological Survey in West Africa: Liberia, Ivory Coast, Ghana, Togo, Dahomey, Nigeria* (Rome: Food and Agricultural Organization of the United Nations, 1966) Vol. I, pp. 1-5.

2. The plow cannot be used because of roots, nor can oxen or horses (provide power) due to the disease trypanosomiasis.

3. Maintenance of animals is difficult during the dry season. Farmers in northern Nigeria give their animals to the Fulani to graze on *fadama* lands.

4. Vegetation grows faster in the crop season.

5. There are many human diseases limiting human energy.

The majority of crops are grown on ridges or heaps, particularly in the savannah. There is a very high seasonal surplus of rainfall in four months and flat land becomes water-logged.

Several crops are grown on the same land with concurrent and sequential planting. A mixed crops system has certain advantages:

1. Soil is entirely occupied, thereby reducing weeds and cultivation.

2. Land is prepared once and produces two crops.

3. There is security against complete failure if one crop fails.

4. The system is very competitive; it increases area and yields when prices are good and continues to produce when prices fall.

The climate is the primary determinant influencing the traditional farmer's decision on what to grow, how to till and when to harvest his crops.

1. Weather may be exceptionally favorable to weed growth.

2. Weather may reduce the time period in which planting or harvesting should be finished.

3. The weather causes uneven distribution of farm work.

4. The weather favors diseases, insects, and illness.

5. The land is very wet during the rainy season; machinery is difficult to use on land subject to tropical downpours.

Labor Inputs

<u>Nigeria</u>

In an economic study of Nigerian villages, Gibbs determined:[2]

1. The average gross product per man-hour was $0.094 for upland and $0.10 for lowland. (This value suggests that the wage rates used in previous tables, based on actual wages paid for hired labor, may be somewhat higher than the value of the average product for all labor in the area.) Income per farm was almost the same, ranging from $115.20 to $116.20 to give equal cash returns for different systems.

2. Labor input per hectare tends to increase as the number of crops in mixtures increases. Crop mixtures giving the highest gross output per hectare

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[2] Gibbs, *An Economic Study of Three Villages in Bauchi Province.*

also yield the highest gross return per man-hour.

Ghana

Some labor requirements for various cropping operations are given for weeding and ridging:[3]

1. Making ridges 90 cm. apart with the West African hoe: 35 man-days per hectare.

2. Making holes for permanent crops (60 x 60 x 60 cm.) and filling with topsoil: seven to eight holes per man-day, or 54 man-days per hectare.

3. Weeding annual crops, light weed growth: 9 to 11 man-days per hectare.

4. Weeding annual crops, heavy weed growth: 17 to 22 man-days per hectare.

5. Ring weeding, 540 cm. radius, permanent crops, 100 to 110 stands per hectare, light weeds: 4 1/2 to 6 1/2 man-days per hectare; heavy weed growth: 11 to 17 man-days per hectare.

Tanzania

The farms range from 1.2 hectares up to 5 to 6 hectares per farm. In the Mwanza area, almost all planting and land preparation is done by hand. It takes one man 52 days to till and plant one hectare of cash crops such as cotton. The smallest farm takes nine weeks to plant, working every day. The farmer also plants 1.2 hectares in food crops which takes another nine weeks, for a total of 18 weeks. This is the maximum amount of land a farmer can handle with hand power.[4]

Ethiopia

Typical work rates and costs for harvesting and threshing are given for several crops:

1) Sesame Harvest and Threshing

In Setit-Humera the cost of harvesting varies from $2.00 to $8.00 per hectare. Since it must be removed from the field before it shatters, the farmers have been forced to pay more to get it cut and stacked in time. At a yield rate of 1,000 kg. per hectare the cost for cutting and bundling is $0.20 to $0.80 per 100 kg.

2) Sorghum Harvest and Threshing

In Setit-Humera the cost of cutting and piling was given as $0.30 per 100 kg. and the cost of threshing with a small stationary tractor-powered thresher as $0.45 per 100 kg. for a total of $0.75 per 100 kg. Mr. Sideris,

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[3] N.L. Ulsaker and P.O. Amponsah, *Ghana Farm Managers' Handbook*, Bulletin A-38 (Accra: Ministry of Agriculture, Information and Publications Unit, 1965), p. 28.

[4] Gibbons, *op. cit.*

an exceptionally large farmer, gave the total cost of harvesting and marketing as $2.92 per quintal, delivered to Asmara. Similar data for an average farmer are tabulated in Chapter II (Table II.45).

TABLE IV.1 COST OF HARVESTING AND MARKETING SORGHUM: SETIT-HUMERA, ETHIOPIA MARCH 1968[a]

Operation or charge	Cost	Total
	$/q.	$/q.
Current selling price at Asmara		4.60
Approximate harvest and marketing costs		
Harvesting, threshing, bagging and sewing	0.80	
Bag cost	0.60	
Hauling from farm to Om Hager across river ($0.70 to $0.80 by hired truck)	0.20	
Unloading from trailer and loading truck	0.08	
Municipal tax	0.04	
Hauling from Humera to Asmara	1.20	2.92
Total income less harvest and marketing costs--balance out of which all pre-harvest production costs must be paid.		1.68

[a]Markos Sideris, Large-scale Farmer in Humera, Ethiopia, Personal Communication, March, 1968.

Land Inputs

Nigerian Studies[5]

1) Norman

Norman's study of three villages near Zaria, Northern Nigeria, ascertained[6]:

1. The larger the holding, the bigger the field size in hectares ranging from 0.024 to 1.87.

2. The larger the holding the greater the fragmentations, from 1 to 20 fields per holding.

3. The tendency for upland fields to increase in size with increased distance from place of residence.

4. In the case of pledge (the right to use land passed to another in return for a money loan) or of loan (land farmed by another individual on a year-to-year basis for a small rental paid at the time of harvest), the temporary cultivator is not inclined to manure or improve the land.

5. The average fertility of the land is unimportant in determining the

[5]Details of the case study in Chapter II (Village Agriculture, Northern Nigeria, p. 2-64) are based on these studies by Gibbs and Norman.

[6]Norman, *op. cit.*, pp. 15-22.

size of holdings, as is land title. A family can have a large-sized holding without land ownership.

6. The average area farmed in all three villages was 3.48 hectares with the most isolated village having the largest farms, averaging 4.1 hectares.

2) Gibbs

Gibbs also studied land use and crop mixtures in Nigeria and reported :[7]

1. Lowland crops were grown exclusively as single crops. Upland crops were grown most frequently as 2, 3, or 4- crop mixtures, with two crops grown most often.

2. As the number of crops in mixtures increases, the yield of individual crops decrease. However, combined yields of millet and guinea corn in 2, 3 and 4- crop mixtures exceeded the yield of either of these crops grown singly.

3. The average value of the gross product per cultivated hectare was $41.50 for upland and $78.84 for lowland.

Cultivation Practices

Hand Tillage

1) Limitations and Constraints

Most constraints apply to mechanization at any level, but the following factors apply particularly to hand tillage:

1. Timing of small rains or length of time from beginning of first rains until crop must be sown is important. In some areas this time is very short and creates an acute labor shortage.

2. If the soil becomes very hard during the dry season, it cannot be plowed or worked until after rains soften it, making timing of planting for optimum yields very critical.

3. If preparation time is limited or soil condition is very difficult, large amounts of labor must be available to quickly prepare land for planting. This labor peak determines how much land a farmer can handle even though there may be surplus labor the rest of the year.

4. Annual crops raised primarily by share croppers or tenants require more intensive cultivation and soil preparation than perennial crops favored by land owners.

5. Because of strenuous effort and length of time required to spade ground with any hand tool, few farmers can afford to use this method except on vegetable gardens.

6. Land preparation by digging hoe may not adequately control weeds and may require more weeding time later. Limited time may not permit thorough tillage.

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[7] Gibbs, *op. cit.*, pp. 17-18.

7. Lack of economic security may reduce farmers' incentive to make investments to improve the physical condition and conformation of the land farmed to make it easier to prepare, till and plant.

8. High population pressure may force the hand farmer to travel a long distance to find land to farm or to select less easily worked or low-productive land nearby.

The farmers' own resources of time, labor, and seed (normally his only monetary input) cannot control nature; the farmer can only work with nature.

2) Need for Improved Hand-tillage Tools

a) Primary Tillage Tools Where animal power cannot be used because of disease (particularly carried by the tsetse fly) and where engine power is not available, the hand-powered farmer is severly limited by the amount of land he can prepare. In northern Ghana and Nigeria, the ground dries out very hard and until the rains start tillage cannot commence.

Minimum-tillage is a plausible alternative for hand tillage. Good steel spades are the best tool for deep hand tillage *if* it must be done. There is a need, however, for a good shovel and fork spade as well as for digging tools. Animal or engine power is the most practical way to increase farm power in present farming systems which require breaking and turning the soil. The use of herbicides and soil conditioners may be the least demanding way to prepare the ground for planting but they are not economically feasible at the present time.

The present Nigerian *garma* is a good steel blade tool where stoop labor is used to make ridges, but it is less suited for flat cultivation. The small Ghanaian *kpakpla* and the Nigerian *fartanya* are used as all-purpose metal blade tools but are definitely limited in their capacity for primary tillage; the Ethiopian *challa* even more so.

b) Secondary Tillage Tools In Nigeria there is a big demand for hand tools in the north but not in the western region. One firm makes machetes and it wants to branch out into other tools. The use of good hand tillage tools and cultivating implements becomes more important with increasing weediness of land under longer cultivation.

Hand Planting

1) Limitations and Constraints

a) Broadcasting All methods of broadcasting are wasteful of seed. Farmers use twice as much seed as recommended for best yields.[8] With present methods of hand sowing and covering, or covering by plowing, much seed is buried too deep, left on top, widely scattered or crowded together.

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[8] Bengtsson, *op. cit.*, p. 23.

b) Row Seeding By hand this is best done by planting in spaced hills or marked rows. Most hill planting on the flat is haphazard with random and variable spacing. Rows should be marked prior to planting with a simple wood or metal gauge.

Mound and ridge farming facilitate row planting, better spacing, more uniform stands and weeding, but they are tremendously demanding in hand labor. The high labor requirements sharply limit the amount of land that can be prepared and planted by hand within the time allowable to get crops planted for maximum yields.

c) Seed Selection Local seed is highly contaminated with weed seeds and impurities, and may be low in viability and germination. Seeds purchased in local Ethiopian markets contained as high as 12 percent weed seed in barley and one or two percent impurities. Seed selected by farmers contained considerably fewer weed seeds, and most farmers apparently plant their own seed and laboriously clean it before sowing to remove the worst adulteration. Bengtsson found:

> . . . seed bought at the market is low in quality, holding almost double percentage of weed seeds and inert material . . . Therefore, a simple cleaning machine would further improve the seed, thus reducing the weed population and increasing the yield.[9]

d) Traditional Practices There are certain rules to follow in order to properly plant according to the traditional system. Bengtsson says,

> . . . the first crop to be planted in the year is often said to be broadcast on a Tuesday and sometimes a Thursday. South of Asella, Ethiopia where barley and flax are main crops, the farmers firmly declare these should be planted on these particular days.[10]

2) Need for Improved Hand Seeding Tools

a) Broadcasting For small grains and grasses more accurate ways of broadcasting are needed to reduce the amount of seed used and to get more uniform distribution and higher plant stands. A crank operated spinner, like a cyclone seeder for hand farmers would be very useful.

b) Covering Improved methods of covering broadcast seed are urgently needed to place seeds at a uniform depth, to cover all seeds so they will not wash away or dry out after they germinate, and to reduce the time, effort and risk in covering by hand, brushing or trampling. A large rake or small harrow could be pulled by two men or an animal to work seed in on small areas. When suitable animal power or small tractors become available, larger harrows can be assembled from the small harrows.

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[9] *Ibid.*, pp. 59-60.

[10] *Ibid.*, p. 22.

c) Cleaning Some method is needed to remove weed seeds, impurities and non-viable seeds. Until such time as improved, tested, cleaned and treated seed can be made available by seed multiplication stations, or until commercial seed is used, hand farmers need better means of processing locally produced, threshed and selected seed for stocks.

d) Row Markers For larger seeds and hill-planted crops, simple row markers are needed to encourage row-planting, spacing, and better weeding techniques. A large rake-like marker with single teeth for each row can be made locally from wood. Beams could have several holes into which pegs could be driven for various spacings.

e) Jab or Dibble Planters While hand hoes and planting sticks are effective in the hands of good workers, simple mechanical devices are needed to permit planting a given number of seeds at the proper depth. Hand planting tubes in the simplest form can be devised to make a standard-size, uniform-depth hole into which the seed can be dropped through a tube from an erect position and covered with the feet. This type of improved planting hoe was developed by Van Beyma for southwest Ethiopia, and was well received by hand farmers.[11]

More versatile dibble planters can be made to eject three or four seeds of maize, beans, or sorghum each time the dibbler is jabbed into the soil, as the operator walks along. As proposed by Cooper, two single dibblers can be joined by a spacing bar of the desired row width. For narrow spacing, one man can operate both dibblers simultaneously; for wide spacing over 90 cm., two men could operate both dibblers in unison.[12]

f) Wheeled Seeder So far, no entirely satisfactory hand-operated push- or pull-type wheeled s der is available for the small farmer. Development work should be continued to perfect an inexpensive, dependable, accurate and versatile, slow-speed seeding unit which could be used for spaced drilling or hill planting.

Hand Weeding and Pest Control

1) Limitations and Constraints

The Nigerian hand farmer's bottleneck problem is weeding, therefore, he only plants what he can weed. Shambaugh asserts that while short-handled hoes are used for weeding and thinning, "we doubt that the individual farmer would

[11] Pieter Van Beyma, Agricultural Missionary, American Presbyterian Mission, Gila, Ethiopia. Personal Communication, January, 1969.

[12] Cooper, "Mechanization on Small-scale Farms and Ox-drawn Equipment, Part II," p. 1.

be able to appreciably increase his acreage by [simply] changing his hand tools."[13]

a) Weeding Frequency and Rainfall Bengtsson reported that all interviewed farmers in Ethiopia are more or less aware of the heavy weed infestation in their fields. Although they know about the importance of proper weeding and suggest frequent weeding as a remedy, they do not practice it.

Rains not only give a flush to all vegetation but provide excellent conditions for re-growth of recently eradicated weed plants.[14] Generally, no hand weeding takes place between plowings or before planting.

b) Effect of Weeds on Yields In the present situation, weeds cause yield decreases due to the competition for light, nutrients, water and, furthermore, many weeds harbor and transmit diseases and give suitable conditions for pests. The present unsatisfactory soil preparation in combination with a surplus of water during the rainy season also stimulates weed growth. Bengtsson emphasizes that "weeds are one of the main limiting factors in order to raise yields. . . . Although the fields have been plowed rather recently to prepare the seedbed , the plowing is by no means very efficient in eradicating weed plants."[15]

c) Effect of Cultivation Practices on Weeding Sommerauer says, "there is a great disparity between the efficiency of hoeing implements and that of weeding methods. The use of improved hoeing implements and row planting should therefore be strongly encouraged."[16]

Haynes states tied ridges that favor soil and water conservation also render weeding more difficult, producing ground conditions in which simple hoeing may not kill weeds unless the sun is unusually fierce.[17]

2) Need for Improved Weed and Pest Control Tools and Practices

a) Limitation of Hand Tools Shambaugh believes the individual Nigerian hand farmer cannot appreciably increase his output by changing his tools. He suggests the farmer can increase production by two methods: by becoming a mixed farmer and using animal power with an Ariana or similar animal-drawn tool carier that will do more than a single tillage operation; or

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[13] Shambaugh, *Summary of the Development in Progressive Mechanization for the Hand and Mixed Farmers in the Savannah of Northern Nigeria*, p. 2.

[14] Bengtsson, *op. cit.*, pp. 45-6.

[15] *Ibid.*, p. 25.

[16] Sommerauer, *op. cit.*, p. 14.

[17] Haynes, *Brief Review of Mechanization Experiments in Northern Nigeria*, p. 18.

by hiring some of his heavy tillage and cultivating done by a mechanized farming contractor.[18]

b) Seriousness of Weed Competition Bengtsson reports the competition in Ethiopia between crop and weed plants is very conspicuous and field investigations confirm farmer's complaints. He says, for broad beans and peas there are 27 and 43 crop plants compared with 898 and 688 weed plants, respectively, per unit area. On an average, over 220 weed plants are found per square meter in fields prepared for planting.[19]

c) Innovations in Weed Control In commenting on the farmer's interest in possible innovations with respect to weed control, Bengtsson suggests how this can be achieved:

> Although chemicals are both available and efficient against some weed species their handling and cost will restrict their distribution at present. Instead emphasis should be put on simple innovations one of which is . . . row planting combined with regular weeding . . . [to] raise the yields. Furthermore, seed could be saved due to less seed rate, and the row planting will give way for the introduction of a simple long-handled hoe which will ease the weeding procedure. Preferably, this could be applied to crops such as maize, sorghum and broad beans.[20]

With regard to possible new approaches to weed control, one farmer stressed crop rotation to decrease the weed flora in cultivated fields and two farmers left heavily weed infested land idle and then plowed it two or three times.[21]

Although this way of thinking is revolutionary to the small farmer, many of them have declared their interest. The results of an investigation of farmers toward new tools is recorded in Table IV.2. The majority of farmers are interested in trying row planting, and those around Kulumsa seem to be convinced of its advantages. As to the increased requirements of labor, there is no objection if it pays.[22]

TABLE IV.2 ATTITUDES OF FARMERS TO THE INTRODUCTION OF ROW PLANTING AND INTENSIVE WEEDING[a] : KULUMSA, ETHIOPIA

Question	Would row planting be an improvement?				Acceptance of the harder work following intensified weeding practice?		
Responses	Yes	Interested	Doubts	No	Yes	Yes, if Convinced	No
	percent				percent		
Total	11	52	26	11	62	32	6

[a]Bengtsson, *op. cit.*, p. 50.

[18]Shambaugh, *Summary of the Development in Progressive Mechanization for the Hand and Mixed Farmers in the Savannah of Northern Nigeria*, p. 2.

[19]Bengtsson, *op. cit.*, p. 60.

[20]*Ibid.*, p. 50.

[21]*Ibid.*, p. 46.

[22]*Ibid.*

d) Use of Long-handled Hoes Seager says, "with improved [long-handled] hoes, the expected hoeing capacity is one acre [0.4 hectares] a day. For hoeing in rows, use a 9 inch [23 cm.] Dutch hoe and teach the cultivator to hoe only where tines cannot reach, and do not attempt to mold ridges."[23]

e) Sprayers for Small Farmers In May, 1967, NIAE conducted a fairly comprehensive test in Malawi on sprayers and found that they could stand only five hours of continuous use. As a result, the Ministry of Overseas Development founded a committee to develop a hand-operated knapsack sprayer able to stand up to roughly 300 hours of work without requiring servicing. A satisfactory knapsack sprayer is being developed for use with all crops, though mainly for cotton. Mr. Le Quinio said a knapsack sprayer with a boom made by Ulysse Fabre in France has accomplished hundreds of hours of work without any breakdowns.[24]

Hand Harvesting, Threshing and Processing

1) Limitations and Constraints

a) Restrictions on Use of Scythe When cereals are reaped with a scythe and cradle, they are cut low. Crops are cut with a sickle to facilitate threshing by animal treading, sled or roller threshers. Cutting with the scythe and cradle therefore presents certain difficulties in countries where these threshing methods prevail.

Grain can be reaped with a scythe and cradle three times faster than with a sickle but flat fields with uniformly standing crops are required. Hopfen says the cradle has been tried in many countries for reaping paddy rice but nowhere has this method been completely accepted because of the high proportion of lodged crops, the soft and tough rice straw and the tendency of the grain to shatter. However, in a good standing rice crop, reaping with a cradle is easy.[25]

b) Restrictions on the Use of Sickle Hopfen further points out that for mowing grass in substantial quantities, the sickle is so slow and tiring, that it discourages cutting forage and making hay in regions where it is the only available harvesting tool.[26] In many semi-arid zones where only the

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[23]A. Seager, *Some Agricultural Engineering Problems Related to the Farm Settlement Scheme of Western Region Report to the Government of Nigeria* (Rome: Food and Agricultural Organization of the United Nations, 1963).

[24]*Minutes of a Meeting of Specialist Committee on Agricultural Machinery Held at Northern Research Center, Tengeru, Arusha, Tanzania*, p. 12.

[25]Hopfen, *op. cit.*, p. 112.

[26]*Ibid.*, p. 100.

sickle is used, straw becomes the basic fodder for domestic animals during seasonal forage scarcity.[27]

c) Lack of Simple Processing Tools In the threshing operation, hand winnowing in the wind often takes no more time and presents more difficulties than the actual threshing.[28]

Suitable processing machinery is needed for small-scale growers. On sisal the most laborious operation is the work of carrying the bundles down the row. A group of consultants recently suggested that since cutting the leaf is a skilled job, efficiency could be improved by carrying the leaf out on stretchers.[29]

2) Need for Improved Tools and Practices

a) Hand Threshers and Winnowers There is a need for more efficient threshing machines for hand farmers. Simple winnowing machines could greatly speed up the grain separating process after threshing. While a fanning mill would be preferable, an efficient crank- or pedal-powered fan to produce an artificial wind would greatly facilitate grain cleaning and processing.

b) Grain Cutting Tools Scythes with or without cradles can greatly increase cutting and mowing capacities of hand farmers growing wheat, barley, and other small grains.

c) Shellers and Decorticators Maize shellers and groundnut decorticators are only used to a limited extent. Demonstrations on how to use and adjust decorticators and small drum threshers need to be conducted.

d) Grain Storage Facilities Better storage facilities are urgently needed by nearly all farmers so they will not be forced to sell crops at harvest time. With good storage, as farmers raise more crops they can store them until needed or sell when market prices are favorable. At present most small farmers store in open rooms or in open woven baskets set on poles and covered with a thatched roof which are very subject to rodent and insect attack.

e) Pest Control Bengtsson cites farmers' interest in innovations with respect to pest control:

> A lot of complaints are expressed by the farmers about agricultural pests. Since quite a few farmers already know about the possible application of chemicals, it was often affirmed that this way of controlling pests ought to be tried. No farmers were in-

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27 *Ibid.*, p. 123.

28 *Ibid.*, p. 126.

29 *Minutes of a Meeting of Specialist Committee on Agricultural Machinery Held at Northern Research Center, Tengeru, Arusha, Tanzania*, p. 13.

different to buying insecticides but 60 percent of the farmers wished to buy provided they could do so at a reasonable price.[30]

f) Processing Grain for Cooking African women work very hard in preparing food. A simple device for semi-mechanizing the traditional method of pounding grain was observed in Asia by Ma. It greatly increased the work capacity and reduced the labor. Ma comments about the treadle mortar introduced (1963) in the Vietnamese villages:

> The mountaineers like it very much and almost every farm household has one unit of this mortar. The treadle mortar has a main beam 3 to 3.8 meters long, pivoted by a wooden axle onto the supporting frame, dividing the beam into two arms at the ratio of 1:2 approximately. The short arm is for the operator to tread. Onto the long arm is [attached] the pounding pestle and below it half sunk into the ground is the mortar. With this equipment paddy rice may be hulled and polished into five kg. of white rice within 20 to 60 minutes.[31]

Animal-powered Agricultural Systems

Importance of Draft Animals in Selected Equatorial African Countries

Far from diminishing in importance, *animal-draft is likely to remain a major source of power for the emerging African farmer for the remainder of this century.* Power available to the small cultivator has not changed since Hopfen pointed out in 1960: "Nearly 85 percent of the total draft power used in agriculture throughout the world is still provided by animals, although the number of agricultural tractors has doubled every ten years since 1930."[32]

Cattle are the main source of draft power in South and East Asia, and in parts of Africa, south of the Sahara, including the Sudan and Ethiopia. Donkeys are the typical pack animals used from Ethiopia to China. Camels are used for transport in the deserts and arid zones from West to East Africa. Few horses or mules are used for agricultural field work in Equatorial Africa.

While animals can carry loads, pulling is best suited to them. Animal draft can be converted into rotary power to operate pumps and other revolving machines, but the power-train and gears necessary for the relatively small amount of low-speed power produced are very costly. This type of power becomes uneconomical when small engines are available and fuel for them is readily obtainable.

Moving from human muscle, animals represent a major step in changing the power in the agricultural system. But wherever used, *increased power must be applied through improved implements in the hands of better farmers* before it can bring about benefits in agricultural productivity. As stated by Cochrane,

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[30] Bengtsson, *op. cit.*, p. 54.

[31] Ma, *op. cit.*, pp. 43-44.

[32] Hopfen, *op. cit.*, p. 8.

"an increase in the availability of power together with improved tools in hands of skilled cultivators determines to a large extent what can be done with basic agricultural resources."[33] Whatever the scale or level of agriculture, the small farmer is a tool user. Further improvement comes more from the introduction of better tools than from increased skill in using old ones. Because labor in Equatorial Africa is generally plentiful, most productive operations on smaller farms can still be done economically with improved animal-drawn and hand-operated implements. The use of improved implements has a direct effect on the production of food and fiber. The CENTO traveling seminars emphasize:

> Effective implements promote and encourage adoption of new farm practices. It is here that the improved farm implements can play their best role. Better cultivation can be achieved either by use of power-driven machinery or by more effectively designed animal- or hand-operated tools depending on the requirements and resources of the farmer.[34]

While engine-powered machinery may be employed successfully in some areas of each country, wherever animal power is appropriate improved types of animal-powered farm implements are needed to facilitate better farming practices such as the controlled placement of fertilizer, row-planting and rapid and effective weeding. Investments in implements and tools are few and limited by the farmers' lack of knowledge, lack of local availability, higher costs of improved implements and the farmer's restricted financial and agricultural resources.

Ethiopia

In the Chilalo Agricultural Development Unit (CADU) project area, Leander made a case study of typical animal-powered farmers in two areas.[35] Some data on one group of farms is presented to describe major tools and oxen and how they are used. Total labor requirements, sources and utilization are also given.

1) Inventory of Tools

Table IV.3 lists the kinds and value of farm tools possessed by farmers. While hay forks and ox yokes apparently are the only tools entirely made by these farmers, grain shovels also are commonly homemade. The average farm investment in tools is very low or slightly over $8.00. Interestingly, the small sickle was valued almost as much or equal to the plow.

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[33]Cochrane, *op. cit.*, p. 31.

[34]Central Treaty Organization, *op. cit.*, p. 16.

[35]Leander, *op. cit.*, p. 157.

TABLE IV.3 FARMERS' INVENTORY OF FARM TOOLS: CASE FARMS, YELOMA, ETHIOPIA FEBRUARY, 1967[a]

Farm	Y1		Y2		Y3		Y4		Y5	
Tool	Number of tools	Value	No.	Value	No.	Value	No.	Value	No.	Value
		dollars		dollars		dollars		dollars		dollars
Ax	2	3.25	1	0.75	1	0.50	1	n.a.	2	1.70
Grain shovel	2	2.00	n.a.	n.a.	1	0.75	n.a.	n.a.	1	1.00
Hay fork	1	n.a.	n.a.	n.a.	3	n.a.	1	n.a.	2	b
Hoe	1	1.00	n.a.	n.a.	1	0.50	n.a.	n.a.	n.a.	n.a.
Ox-yoke	3	n.a.	1	n.a.	2	n.a.	1	n.a.	1	b
Plow	3	6.00	1	1.50	2	3.50	1	2.50	2	3.00
Sickle	1	0.75	2	2.00	3	2.25	2	2.50	3	2.25
Spade	1	1.00	n.a.	n.a.	n.a.	n.a.	1	1.50	n.a.	n.a.
Total Value		14.00		4.25		7.50		6.50		7.95

[a]Leander, *op. cit.*, Table 2, p. 20.

[b]Locally made by farmer; value not estimated.

2) Number and Utilization of Oxen

All Yeloma farmers involved in Leander's study use their oxen in work on the farm; the jobs are plowing, threshing and transportation. Plowing is by far the most time consuming while transportation of the crop on a kind of sled to the threshing place constitutes only a minor share of the oxens' total work. Table IV.4 shows that farmers on the average use their oxen only about 30 percent of the working days. Even during the peak work periods during plowing farmers use oxen to only 70 percent capacity. The average number of oxen per farmer is 3 to 4.

TABLE IV 4 UTILIZATION OF OX-POWER BY FARMERS: YELOMA, ETHIOPIA, 1967[a]

Farm	Number of oxen	Number of oxen-days performed per year	Number of oxen-days maximum capacity[b]	Average utilization A÷B	Number of oxen-days performed in a peak week[c]	Number of oxen-days maximum capacity in a peak week	Maximum utilization C÷D
	average	A	B	percent	C	D	percent
Y1	6.0	230	1,314	18	24	36	67
Y2	2.0	108	438	25	10	12	83
Y3	4.5	342	986	35	18	27	67
Y4	3.0	182	657	28	12	18	67
Y5	2.0	178	438	41	8	12	67
Average	3.5	208	767	29.4	14.4	21	70

[a]Adapted from Leander, *op. cit.*, Table 22, p. 57.

[b]After deduction of Sundays and holidays, 219 working days remain per year.

[c]A peak week is six working days.

3) Ox-power Required per Cultivated Hectare

The Table IV.5 shows a calculation of the amount of ox-power required for each hectare of cultivated land for all crops.

TABLE IV.5 UTILIZATION OF OX-POWER PER HECTARE CULTIVATED LAND: YELOMA, ETHIOPIA, 1967[a]

Farm	Total number of ox-pair days used on the farm	Cultivated area hectares	Number of ox-pair days per hectare cultivated land
Y1	115	4.88	24
Y2	54	1.27	43
Y3	171	4.10	42
Y4	91	4.12	22
Y5	89	1.81	49

[a]Adapted from Leander, *op. cit.*, Table 14, p. 45.

4) Labor Input Per Cultivated Hectare

Below is an estimate of the labor in crop production in relation to total farm labor. Labor in crop production accounts for approximately 60 percent of productive tasks. Calculated also is the amount of man-hours worked per hectare of cultivated land. No distinction has been possible between different crops.

TABLE IV.6 LABOR INPUT PER CULTIVATED AREA OF CROPLAND FOR OX-PLOW FARMERS: YELOMA, ETHIOPIA, 1967[a]

Farm	Labor in crop production	Total farm labor[b]	Labor in crop production as percentage of total farm labor	Total cultivated land	Number of man-hours in crop production per hectare cultivated land
	man-hours	man-hours	percent	hectares	man-hrs./ha.
Y1	1,399	3,254	43	4.88	287
Y2	965	1,373	70	1.27	760
Y3	2,118	3,775	56	4.10	517
Y4	1,341	2,582	52	4.12	326
Y5	1,396	2,557	55	1.81	771

[a]Adapted from Leander, *op. cit.*, p. 42.

[b]Activities in crop production and animal husbandry.

5) Farmers' Use of Working Hours

The utilization of all available working hours during one year of farming and related activities by the same group of ox-plow farmers in Ethiopia was recorded by Leander. For these farmers the work of crop production accounts for less than one-third of their work time. Taking care of livestock took about one-tenth of total work time. Other activities included: going to market; gathering fuel; fencing and housebuilding; work for others; leisure time; sickness and miscellaneous tasks such as court attendance and elder meetings. All but one spent more time in leisure activity than in the field.

In addition to the farmers' labor, extra help was used for farm tasks of crop production and animal husbandry. The wife and other family members supplied most of this extra labor although outsiders were also used for 5 to 10 percent of this work, apparently in exchange for similar help.

6) Interest in Better Farming Methods

In a survey of every 25th farmer in the CADU project area, the extension agents found that *all* were interested in changing their present farming methods.[36] Almost all believed they could increase the output from their farms with 1) better seeds, 2) better plows, 3) fertilizers, and 4) more frequent weeding. More than half thought that better hand-hoes, insecticides, better storage, more and better grassland and up-graded cattle also would be good.

The survey indicated that 31 percent of the farmers burn fallow land sod in heaps before planting. Over two-thirds said that they used some manure to fertilize crops: 32 percent fertilize wheat, 59 percent barley, 43 percent maize, 27 percent beans and legumes and 19 percent sorghum. Manure was used by 73 percent of all farmers for fuel and 70 percent used wood. Ninety-nine percent of farmers reported they had rodent problems with their stored grain, and 39 percent said they were troubled with insects. Of all farmers, 55 percent reported their land was eroding but they were not doing anything about it. Extension agents classified 26 percent of the farms as having severe erosion and 29 percent with mild erosion.

Tractors and plows are rented to a certain extent in Asella and around Kulumsa. Bengtsson reported that it is "limited to those few who can afford it (8 percent) although about 40 percent would prefer tractor plowing."[37] A fairly high proportion of the farmers south of Asella (27 percent) have *not seen* a tractor and modern plow. The efficiency of a tractor plow was considered far more effective by those aware of it.[38]

Ghana

1) New Areas for Potential Mechanized Farming

Soils are sufficiently level for potential mechanization on a small, narrow strip of land along the seacoast east of Accra. Here the rainfall is 76 to 102 cm., the lowest in Ghana. The soils are mostly Sodium Vleisols, Savannah Ochrosols, Regosolic Ground-Water Laterites, Tropical Black Earths, and Acid Vleisols. If irrigation water were made available from the Volta River dam at Akosombo, this area would have a moderate potential for mechanized farming.

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[36] Chilalo Agricultural Development Unit, *General Agricultural Survey of the Project Area*, p. 34.

[37] Bengtsson, *op. cit.*, p. 15.

[38] *Ibid.*

The area of greatest potential for mechanized agriculture, however, is northern Ghana, comprising the northern half of Brong-Ahafo region and all of the Northern and Upper Regions. This area contains approximately 11.7 million hectares with an estimated present cultivated area of less than 5 percent.

In northern Ghana the land is fairly level and rainfall averages 114 cm. a year, 95 percent of which falls during the six-month period from April to October. This rainfall pattern is satisfactory for producing most tropical annual crops. Furthermore, a large (but as yet undetermined) part of the area can be irrigated from the backed-up Black Volta and White Volta Rivers as a result of the dam at Akosombo in southeastern Ghana on the main Volta River.

The area of greatest potential mechanization in Ghana lies between 7° 31' and 11° north latitude (to the northern border between Ghana and Upper Volta) and extends east and west to the borders of Togo and Ivory Coast respectively; (it also extends into Northwestern Togo, southern Upper Volta, and Northeastern Ivory Coast).

2) Farm Size Needed to Own an Ox Team

It has been estimated for northern Ghana that an area of 4-6 hectares of crop land is necessary to justify a farmer's owning a pair of oxen.[39]

Nigeria

The number of animal-powered mixed farmers (35,951 in 1964) is very small in relation to the 4 million hand farmers in the northern region. In this connection the following limiting factors are mentioned by Alkali (1964).[40]

1) Lack of Capital

A considerable number of rural people in the past have been unable to establish themselves in farming through lack of sufficient credit facilities in the Nigerian Native Authorities to purchase the required cattle and equipment. Provision of $2.24 million was made under Project 13 of the 1964 Development Plan to provide additional facilities for over 5,000 new farm owners per year. Administration of this scheme pivoted on northern Nigeria's system of local government and heredity laws.

2) Effect of Tsetse Fly

The incidence of trypanosomiasis restricts cattle-keeping south of the line of latitude 10°, though considerable expansion is possible south of this line in Bauchi and Adamawa Provinces. The onward spread of tsetse since 1944 has severely affected mixed farming in some areas, notably Zaria Province.

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[39] See Table II.27.

[40] M.M. Alkali, *Work Animals and Integration of Cattle in Mixed Farming in Northern Nigeria* Paper presented at General Annual Conference, Nigerian Agricultural Society (mimeographed) (Ibadan: Papers on Agricultural Engineering in Northern Nigeria, October, 1964).

Efforts at treatment have shown that in settled cattle, drug resistant strains of trypanosomes soon develop. In the light of this difficulty, the region has been divided into areas of encouragement, doubtful, and discouragement.

3) Wastage of Resources

Part of the wastage of resources is due to animal losses caused by trypanosomiasis and other diseases. Funds from hiring charges are used for some measure of insurance and replacement. A major part of the loss is due, however, to lack of thrift and management which causes many farmers to succumb to seasonal shortages of animal feed or other difficulties. The development of cooperative thrift and other societies is expected to overcome this.

4) Staff Shortage

The agricultural extension staff is not responsible for collection of debts or other routine duties associated with the Mixed Farming Scheme. However, great improvements are needed in both the quality and the numbers of extension workers in mixed farming areas, and indeed in all areas. Intensive training programs for all staff levels, outlined in the 1964 Development Plan, were aimed at providing one extension worker for every 2,000 farmers by 1968. During slack times of the farming year, intensive courses on specific subjects are provided at provincial and regional levels. In addition, the Ministry's Farm Institutes Program is intended to provide a nucleus of trained young farmers to lead agricultural development in all administrative divisions of the North.

5) Optimal Sized Holdings

Over half of the mixed farmers have less than 8 hectares of land, especially in the closely farmed areas around large population centers. Some consolidation has occurred but many still have a number of scattered fields and collect their cattle feed, both grazing and cut fodder, outside their farms. In establishing new mixed farmers, the aim is for each farmer to have the use of as much undivided land as is consistent with the land resources of the area, with a minimum of 8 contiguous hectares. In Katsina and parts of Kano Province, a more intensive system embracing the heavier use of fertilizer and feeding stuff is followed, and mixed farmers perform contract cultivation for neighbors.

<u>Tanzania</u>

1) Present Methods of Ox-Cultivation[41]

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[41]A. Scaife, Research Officer I, *An Ox-drawn Implement for Weeding and Tie-Ridging* Progress Report No. 10 (mimeographed) (Ukiriguru, Tanzania: Western Research Centre, January, 1967).

Ox-cultivation is the dominant method of farming in most parts of Shinyanga region, and in other western and northern areas. Almost invariably this means flat-plowing and broadcast seeding followed by hand weeding with *jembes*. The oxen used vary in number from two to twelve per team with one to three men to drive. The standard of plowing is generally high, but for weeding it is less than adequate.

2) The Weeding Dilemma of Ox-powered Farmers

Collinson, in 1963, illustrated the dilemma of farmers who cultivate by oxen. He surveyed 62 farmers in Maswa, of whom 31 used their own oxen for cultivation while most of the remainder hired either tractors or oxen. The major effect of changing from hand cultivation to ox cultivation was to transfer the labor peak from primary cultivations to weeding, as shown in Table IV.7.

TABLE IV.7 LABOR INPUTS FOR MAIZE AND COTTON: TANZANIA[a]

Crop and operation		Flat land (ox)	Ridge (hand)
		- - - man days per	hectare - - -
Cotton:	Primary cultivations	10	50
	Weeding	64	37
Maize:	Primary cultivation	12	84
	Weeding	18	22

[a]Adapted from Collinson, *Farm Management Survey Report No. 3.*

Collinson showed that with flat planting, the inputs required per hectare fell from 50 and 84 man-days for cotton and maize, to only 10 to 12 man-days, respectively. This is a measure of the potential impact of an ox-plow and flat cultivation on the traditional system. He concluded, "the potential increase in labour efficiency through increased acreage from flat cultivation is reduced by the extra labour input required for weeding . . . It is certain, however, that no significant benefits have accrued to those farmers who have invested [only] in an ox-plough."[42]

There can be little doubt that the weeding problem is now the major factor limiting expansion of both yields and area where ox-plowing is established, but where efficient weeding tools and methods have not been introduced.

3) The Decline of Ridging and Tie-ridging

Ridging, not to mention tie-ridging, has been almost completely abandoned in ox farming areas of Tanzania, despite the fact that on research stations, tie-ridging, as opposed to flat cultivation, has been found to give definite yield increases, especially in the semi-arid areas such as Shinyanga where ox cultivation predominates. Tie-ridging by hand requires about 15 more man-days of labor per hectare and Collinson points out that on an average this labor

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[42]Collinson, *Farm Management Survey Report No. 3, passim.*

can be used more profitably to extend cultivated area.

The desirability of tie-ridging most soil types to prevent loss of rain water and top soil is undeniable.[43] Until now, however, very few farmers have found it profitable. Besides the extra labor, plant populations and fertility levels in ridges have been discouragingly low.

4) Use of Ox-ridgers and Inter-row Cultivation

Rounce, in 1949, said the ox plow should be discouraged on lighter soils because of the danger of erosion.[44] Attempts were made to introduce an ox-drawn plow to make 152 cm. ridges, but it proved impractical because of the high draft required. The normal 92 cm. ox-ridger has been in disfavor because the ridges were not considered large enough to withstand erosion.

At Ukiriguru, during the last five years, there has been a gradual change from 127 cm. to 92 cm. ridges to allow tractors and work oxen to get into the crop for spraying and inter-row cultivation. Experiments show no consistent yield differences between crops grown on either ridge. With maize and cotton, only one crop row is planted on a 92 cm. ridge as compared with two on a 127 cm. ridge. The center strip on top of the wider ridge cannot be reached as effectively by cultivation implements.

The normal method of inter-row cultivation with oxen is to pass through the crop, first with a five-tined cultivator and then with a ridger to reform the ridges. The latter used by itself scrapes weeds more effectively from the bottom of the furrow than from the sides of the ridge. The cultivator tends to dig deeply into the sides of the ridge. Two operations are necessary, reducing the work rate to about 0.3 hectare per day and ties must be added by hand.

5) A Tie-ridging and Weeding Attachment for Ox-ridgers

Stokes, in 1963, devised a simple implement to do weeding and tieing with one operation with two well-trained oxen.[45] It consists of half a worn 66 cm. tractor plow disk, mounted transversely on a short beam which hinges on the beam of an ordinary ridging plow. The disk is raised and lowered with a handle by the operator and the oxen are yoked with a 2.45 m. yoke so they walk in alternate ridges. Cost of the locally-made unit is about $5.00. The rate of work is about 0.6 hectares per day, or three times as fast as regular plowing.

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[43] Scaife, *op. cit.*, p. 2.

[44] N.V. Rounce, *The Agriculture of the Cultivation Steppe* (London: Longmans, Green and Co., 1949).

[45] A.R. Stokes, "Mechanisation and the Peasant Farmer," *World Crops*, Vol. XV (December, 1963).

Ridging provides planting lines which are an essential prerequisite for inter-row cultivation and, provided the ridges are on contour, can increase rainfall retention and infiltration. In operation the tie-ridger scrapes soil from the furrow and deposits it as a tie, by lifting the disk handle about every three meters. The tie-ridging attachment also cleans the ridge sides, which the ridger does not do satisfactorily. Work quality depends mainly upon straight and uniform ridge width. Under ideal conditions it is possible to reduce the amount of hand-weeding to the minimum.

Ridging on Tropical Black clays is not feasible with a disk plow, or with oxen power because of the hardness of the soil. For such soils, the Ukiriguru Western Research Station recommends flat-cultivation as appropriate.

Cultivation Practices and Animal-powered Tools

Land Preparation

1) Limitations and Constraints

a) Disadvantages of Indigenous Breaking-plows They have very low working capacities; land must be plowed three to four times. Since the soil is not turned over, the weed seeds are not buried deep enough to prevent new germination and plowed fields become very weedy. The points have ineffective cutting action simply pushing aside weeds with tough roots. Inadequate plowing makes it impractical to turn under green manure plants and to grow fodder crops for livestock feed.

b) Lack of Sharp Tools Gabathuler reported tools in Ethiopia are never sharpened although there are many sources of good sandstone. Dull tools cause much waste of material, effort and time, and especially for plowing, the working time is very high.[46]

c) Increased Erosion Improved plows and more power for effective tillage and weed control requires greater emphasis on soil and water conservation measures. The land will not be as rough and resistant to erosion since tillage is deeper and more vegetation will be buried. Deep plowing alone greatly increases the danger of erosion. Plowing must be done on the contour, and rows planted across the slopes. Strip-farming may need to be practiced along with terracing, use of grassed waterways and sod crops in rotations. More research is needed on the economics, practicability and implementation of such systems. The increased use of manure will also cause greater weeding problems unless it can be buried deep enough to prevent weed seeds from germinating. Hopfen states the breaking *ard* has advantages from the viewpoint of

[46]Gabathuler, *op. cit.*, p. 4.

erosion control:

> The technical features, low cost, simplicity of design and ease of operation possessed by breaking *ards* are advantages which should not be underestimated, especially for moisture conservation in regions particularly exposed to wind and water erosion. Their disadvantages . . . do not justify attempts to substitute them with moldboard plows in the aforementioned regions [including parts of tropical Africa][47]

2) Need for Improved Animal Tillage Tools and Practices

a) Requirements for a Successful Plow The basic requirements for a successful plow bottom are the same whether it is animal- or tractor-powered. The size, weight and shape of the plow should be suited to the soil conditions and power available. There should be a choice of moldboards to suit different soil conditions. Soil moving parts should be made of high carbon steel or special soft center plow steel to assure long wear and good scouring. Wearing parts should be easily removed for sharpening or replacement. Shares should be made of the best available material and kept sharp. Dull or improperly made shares waste power. About 50 percent of the power required in plowing is used by the share. Easy and accurate adjustments are needed to control the depth of plowing and width of furrow. This can be accomplished on animal-drawn plows by changing the hitch-point, or providing holes or wedges to change the angle of the beam. A front gauge wheel is desirable on dry soils but is impractical on wet sticky soils typical of many parts of Ethiopia.

b) Improved Soil Stirring (Chisel) Plows Plows of the non-inverting chisel-type are used in certain areas of each region of Equatorial Africa. Chisel-type plows, both animal- and tractor-drawn, are preferred for certain soil and climatic conditions, particularly where stubble-mulch-farming is practiced. In semi-arid regions where soils are subject to wind and water erosion, adaptive research is needed. Some excellent results were observed in northern Tanzania on large wheat farms using chisel plows, minimum tillage and strip farming techniques.[48] Various improved interchangeable shares and sweeps have been fitted for more thorough tillage and effective weeding. Equipped with ridging bodies or other working parts, this modern *ard* becomes a multi-purpose implement.[49]

c) Improved Moldboard Plow The idea of an improved moldboard plow is not new. On the advice of Gabathuler, some experimental plows were made in 1953 by a private firm in Ethiopia. Satisfactory both in construction and performance, their cost was about $12.00 to $16.00. The weight of the plow,

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[47] Hopfen, *op. cit.*, pp. 59-61.

[48] John McCartney, Agronomist, Northern Research Center, Tengeru, Arusha, Tanzania, Personal Communication, October; 1968.

[49] Hopfen, *op.cit.*, pp. 59-61.

without beam, was 14.5 kg. and the traction power required about 200 kg. Its performance in heavy soils and under dry conditions was good, permitting plowing of two to three times as much per hour as the local plow.[50]

d) VITA, Improved Moldboard Plow for Oxen In Asia, VITA tested existing moldboard plows for suitability to local conditions. One considered best adapted to Afghanistan has possibilities for use in Equatorial Africa. In tests by CADU in Ethiopia, it performed very favorably. The plow has been given the name "village plow" because it can be made by local blacksmiths. All other plows tested were of the Western-type, modeled after horse or tractor-drawn plows. When used with oxen as straight-pole plows, they are unwieldy and hard to control. In contrast, the village plow handles well with its long low share, and can be controlled as easily as the local wooden plow, and scours better in heavy soils.

Rivets are used entirely in the construction of the village plow because farmers lack wrenches to tighten bolts. Even the share is riveted to the moldboard so that it can be easily replaced by the village blacksmith. Riveting prevents loss of parts due to bolts becoming loose. Wooden wedges in the pole bracket adjust the plow for depth of plowing. Raising the pole in the bracket allows the plow to go deeper into the soil, while lowering the pole lets the plow run shallow. The plow is adjusted so that the back of the landside runs as close as possible to the bottom of the furrow while plowing at the desired depth.[51]

e) Wood-bar Peg-tooth Harrow The CENTO traveling seminar describes a simple harrow very suitable for use in Equatorial Africa.[52] The low-cost wood-bar peg-tooth harrow is designed for animal or tractor power. Flexible linkage between the bars helps to give the harrow a self-cleaning feature. Teeth are spaced 20 cm. apart and the bars offset to give an average tooth spacing of 5 cm. The harrow can be made in any length to suit the power available. The linkage is arranged to keep the teeth erect while in use but still permits them to tip back and release accumulated trash.

Weeding and Inter-row Cultivation with Animal Power

1) Limitations and Constraints

a) Seriousness of Weeds In Equatorial Africa present methods of land preparation by ox plow in combination with a surplus of water during the rainy season facilitates weed growth. With low standards of cultivation, a

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[50] Gabathuler, *op. cit.*, p. 7.

[51] Volunteers International Technical Assistance, (VITA) *Moldboard Plow for Use with Bullocks*, n.d.

[52] Central Treaty Organization, *op.cit.*, p. 117.

very serious problem exists in most farmers' crops. Bengtsson says, "about 60 percent of the interviewed [ox-plow] farmers are of the opinion that weeds are the greatest problem in crop production. Assistance in the combat of noxious weeds is often requested and it is quite understandable that the laborious hand picking procedure is far from sufficient. A solution will require not only a simple but also an efficient method with frequent weeding."[53]

b) Soil burning Soil burning is practiced in certain areas of Ethiopia, particularly south of Asella. Bengtsson reported that "in some cases weed growth is decreased, e.g., weed seeds are destroyed during the burning. . . . It is almost the only way of getting rid of all grasses and their roots, since the present plough is short of moulding properties and so the organic material can not be mixed with the soil."[54]

c) Proportion of Weeds to Cultivated Plants Bengtsson reported that in Ethiopia, at the end of August there are about five times as many weed plants in unweeded wheat fields as there are crop plants. The average number of weed plants exceeds barley and flax plants three times and maize plants 28 times.[55] A disadvantage of manuring crops is mentioned by farmers who complain that though manure is important for the crop, it also considerably increased weed growth.[56]

2) Need for Improved Animal Weeding Tools and Practices

a) Land Preparation for Weed Control To effectively destroy weeds in land preparation a better plow is needed. An improved type moldboard plow can greatly aid the farmer in controlling weeds in adequate rainfall areas where it is desirable to turn under vegetation for green manuring and to dispose of heavy vegetative growth. Bengtsson reported:

> "Very few farmers know about a better plough. Nevertheless, 82 percent of the interviewed farmers have a longing for a better soil preparation implement." [Furthermore,] "in case an improved plough is made available, stronger animals, for instance mules, must be provided." [He says,] "35 percent of the farmers showed an interest in keeping mules as draught animals provided they got the equipment needed and were trained in the handling of it."[57]

b) Shortcomings of the Ridger for Weed Control In Ghana and Nigeria, most ox-power farmers have only one implement, the ridger. With it they do all basic operations including land preparation, in-furrow weeding and

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[53] Bengtsson, *op. cit.*, p. 26.

[54] *Ibid.*, p. 11.

[55] *Ibid.*, pp. 26-27.

[56] *Ibid.*, p. 11.

[57] *Ibid.*, pp. 14-15.

by removing the moldboards, groundnut lifting can be accomplished. With the ridger they cannot weed the ridge tops which must be cultivated by hand. The technique of ridging the old furrow to clean out the weeds before splitting the old ridges into it, helps to reduce weeds in the new ridge. Weeders can be devised for ridge cultivation but it takes more power to retie the furrows and to re-bank the ridges. Planting on the flat offers advantages in weed control which are simpler and less costly.

c) Need for Research in Weed Control Haynes reported on ridge weed control in northern Nigeria:

> In the majority of cases where weed scores or labor required for weeding have been recorded, direct splitting of ridges has given better control than any other type of cultivation in the first season. This is probably due to the action of the lister-type ridgers which bury the seeds lying on the surface deep inside the new ridge. It is not clear, however, whether the benefits of direct splitting will persist when these buried seeds are brought to the surface by splitting in the following year. Successful crops have been raised under mixed farming conditions by combining hoeing and reridging but where tractors are used, some hand weeding is usually necessary after the crops become too tall. The conditions which favor water and soil conservation (e.g., tied ridges) render weeding more difficult, producing ground conditions in which tractor work is difficult or impossible, and in which simple hoeing may not kill weeds . . . Thus although the current cost of herbicides is high, chemical control may eventually be unavoidable and new herbicides should be tested regularly.[58]

d) Improved Ridger Attachments for Weed Control Shambaugh writes,

> We have a prototype weeding attachment for the Emcot plow and will give it field trials [1969] before we release it or write a report. It will weed between the row, cutting down the ridges and then the ridger will remold them. We hope by this groundnut and weeding attachment for the 60,000 Emcots in the North to possibly educate the farmers that other attachments are useful and possibly lead them toward buying Arianas with the attachments.[59]

e) Adoption of Row Weeding In Ethiopia, Kenya, Tanzania and other parts of East Africa where it is not now practiced, row planting must be promoted to permit more efficient use of animal-powered cultivators and hoes. The use of lightweight, inexpensive multi-purpose single-row hoes and multiple-row toolbar cultivators would greatly increase weeding capacity and efficiency. The single-purpose one-row three-tooth cultivator can help the plow farmer solve one of his worst bottlenecks.

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[58] Haynes, *A Brief Review of Mechanization Experiments in Northern Nigeria*, p. 18.

[59] T.J. Shambaugh Jr., USAID Farm Machinery Advisor, Industrial Development Centre, Samaru Zaria, Personal Communication, March, 1969.

Planting and Seeding With Animal Power

1) Limitations and Constraints

In the light sandy soils of Senegal, Mali and Gambia, very little basic tillage is needed and the bulk of labor is used in secondary tillage and planting to get the crop in as soon as possible after the rains start.

a) Effect of Planting on Weeding In Nigeria and Ghana with hard dry soils which must be softened by rains, the major limitation is primary tillage for the hand farmer and usually weeding for the animal farmer. Since the ridger can be used only for weeding in the furrows, the farmer has more inter-row weeding to do as he expands his area with animal-power. Thus the quality and the rapidity with which he is able to weed depends primarily on the way he plants and how it facilitates the later weedings.

In Ethiopia the broadcast method of seeding results in poor coverage, germination and distribution. Land preparation does not eradicate the weed plants and uncleaned seed adds more weeds to increase the competition. In addition the random plant spacing prevents efficient inter-cultivation and any weeding in small grains and legumes must be laboriously done by hand.

b) Effect of Early Sowing In Tanzania planting was reported to be the crucial operation in cotton production. Cotton is especially sensitive to moisture, and early planting is essential to good yields as borne out in experiments by the Institute of Agricultural Research in Ethiopia.[60]

In Nigeria, Haynes reported, "in another trial at Dambolta there was a marked decrease in yield with late planting of upland rice."[61]

Early planting	2 April	Yield	4668 kg./ha.
Late planting	4 June	Yield	3035 kg./ha.

c) Effect of Ridge Planting Ridge farming has long been advocated in many areas of Equatorial Africa to prevent erosion, to conserve water and to increase yields. Ridges, however, hamper mechanical planting and weeding of crops. Shambaugh reports: "After five years of mechanical cultivation of crops on both the flat and on ridges, we can see no advantage to ridge farming in this area [northwestern Nigeria]."[62] More research data

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[60] Melka Werer Research Station, *Progress Report for Period February, 1966 to March, 1968*, p. 8.

[61] Haynes, A *Brief Review of Mechanization Experiments in Northern Nigeria*, pp. 13-14.

[62] Shambaugh, *Bornu Complete Tillage Machine*, p. 1.

are necessary to give clear evidence on the appropriateness of ridge cultivation in different areas where it is being used. Such experimental work should be sufficiently related to local environmental conditions.

2) Need for Improved Animal Seeding Tools and Practices

a) Leveling Harrow for Covering In Ethiopia the fourth plowing is a substitute for harrowing to cover the seeds. Bengtsson says:

> . . . the seeds are ploughed down in the soil . . . There is no leveling of the land before planting. Instead there are furrows which are quite deep and wide with respect to seed covering . . . This practice . . . explains the relatively high seed rates that are used.[63]

There is a definite need for some type of spring-tooth or spike-tooth harrow for leveling land prior to planting, for covering broadcast seed to a uniform depth, and for reducing the work. A mechanical cyclone seeder for more accurate broadcasting also is desirable.

b) Seed Cleaner The purity of seed presently used by most farmers is contaminated with both weed seeds and inert matter. Both animal-powered and hand-powered farmers improve their seed before planting by hand cleaning.[64] A simple hand or foot-operated winnower or fanning mill is needed.

c) Row Marker and Seed Drill Except where ridging is practiced or certain market oriented cash-crops like cotton and groundnuts are raised, most crops are still planted by broadcasting or random hand-spacing by ox-plow farmers. The farmer who plants by hand on the flat, needs a simple row-marker. Larger farmers need a simple seed drill for row sowing at a uniform depth for good germination and uniform spacing for subsequent weeding. In drier areas this unit should be able to plant in trash mulch to a uniform depth without blockage; it could also apply fertilizer.

d) Row Planters For the farmer who wishes to mechanical plant row crops, there is a need for a simple inexpensive seed planter to sow a variety of seeds at selected rates. Stephens mentions "the development of a simple cheap seeder is a matter of the highest priority. Various seeders were tested but none proved completely satisfactory . . . A cheap, simple seeder giving accurate planting for a variety of crops has still to be developed."[65]

Cooper tested various types of seeders to find suitable equipment to plant Kenya Hybrid maize. He says, "the high price and scarcity value of

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[63] Bengtsson, *op. cit.*, p. 7.

[64] *Ibid.*, p. 59.

[65] Brown, *et al.*, Chapter 17.

this seed calls for efficient seeders . . . The machines having a metal rotating agitator over a series of graduated holes were the most consistent in work although better inter-plant spacing was desirable." Rotating brush-agitators adjacent to graduated holes were satisfactory, provided the bristles were bunched together to give a paddle effect. All planters required a fairly smooth seedbed and, when planting to the desired depth, it was necessary to fit a special coulter. When mounted on toolbars they required specially designed spring-loaded arms to apply pressure on the drive-wheel at the correct angle to maintain positive drive.[66]

Harvesting and Threshing with Animal Power

1) Limitations and Constraints

a) Effect of Field Length Haynes points out for wheeled tools there is a minimum length field that permits efficient operation. He says:

> The comparison of the turning times of the Samaru Lifter and the Kano King is of general interest. The Samaru Lifter, having two wheels must be turned in the same way as the wheel toolbars which are sometimes advocated (APLOS, Attele, etc.). While it has been obvious that such implements would be at a disadvantage in small fields, it is now possible to suggest a very tentative size of field -- *i.e.*, less than 95 yards [87 meters] long -- for which wheeled implements are unsuitable.[67]

b) Effect of Hard Soil Conditions Under very hard soil conditions it may take much time and be almost impossible to dig groundnuts; blades may have to be sharpened frequently and gleaning losses may be high. Haynes says, "the condition of the soil, rather than the percentage of gleanings, influences the time taken and any differences are likely to favour implements such as the Samaru groundnut lifter and Ariana, which leave the soil well broken."[68]

c) Effect of Unsuitable Implements While the Emcot ridger is commonly used by western Africa farmers for groundnut lifting with the wing moldboards removed, Haynes points out, "the working rate figures do not reflect adequately the difficulty of doing a good job with the Emcot. Highly skilled ploughmen have difficulty in keeping the share in the right place and the work is very fatiguing."[69]

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[66]Cooper, "Mechanization on Small-scale Farms and Ox-drawn Implements, Part I," p. 1.

[67]Haynes, *Interim Report on Tests of Ox-drawn Implements as Groundnut Lifters*, p. 61.

[68]*Ibid.*, p. 56.

[69]*Ibid.*, p. 58.

d) Effect of Threshing Method on Grain Quality The amount of broken seeds in small grains is influenced by the threshing method. However, Bengtsson reported that "traditional threshing with oxen gave only 0.1 to 0.2 percent of broken seeds, whereas the use of a threshing machine caused a percentage of broken seeds of almost 2 percent, or 10 times as many."[70]

An FMC study team, in commenting on crops threshed by trampling in Ethiopia said, "crops threshed by trampling out grain with horses or cows . . . recent tests have indicated that from 30 to 35 percent of grain is not recovered from the threshing floor."[71]

e) Effect of Threshing on Oxen's Health The threshing operation, extending over two months of dry weather, is very hard on oxen used day after day to trample out grain. They are frequently muzzled and may not receive adequate amounts of water. Fischer says the continuous stress on the oxen results in many animal deaths in Ethiopia.[72]

f) Effect of Improved Varieties and Yields The high labor requirements for threshing can be met when yields are low from small areas, but with larger yields from improved varieties and improved agricultural practices the volume of work will be multiplied. It may become so great as to extend into the next rainy season or conflict with other farm operations. In any case, threshing will become more costly, time will become a limiting factor and losses may increase beyond acceptable limits if traditional methods are used to process harder-to-thresh varieties.

2) Need for Improved Animal Harvesting Tools and Practices

a) Improved Groundnut Lifters In addition to the ridging or breaking plow, the only animal implement owned by most farmers, additional tools are needed to assist with particularly difficult, timely or critical operations for high value, high volume crops. Most farmers in Nigeria and Ghana use the Emcot ridger minus its moldboards for groundnut lifting. It greatly increases the amount of hand labor to wind-row and dig out the nuts. A special attachment is needed to convert the Emcot into a lifter. Shambaugh with the Industrial Development Center (IDC) in Nigeria has developed such an attachment and the designs have been tested and approved for use by farmers. He writes, "Kano State exhibited our groundnut lifter attachment

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[70] Bengtsson, *op. cit.*, p. 21.

[71] FMC, *op. cit.*, p. C-14.

[72] John L. Fischer, USAID Agricultural Officer, Addis Ababa, Ethiopia, Personal Communication, January, 1969.

at their agricultural fairs and the Ministry of Agriculture has requested 40 of them to be built right away. We are having a seminar for blacksmiths next week for making groundnut lifters."[73]

b) Animal Threshing Tools The traditional way of threshing with animals' hooves in Ethiopia is very laborious and time consuming. The product is extremely dirty and is laboriously cleaned by winnowing in the wind. Although a very few communities have contract or hire-services for mechanical threshing, the vast majority of small African grain farmers must depend upon themselves and locally available tools. Improved devices such as threshing-sleds, rollers and disks should be tried and evaluated. Improved implements could be manufactured locally to stimulate small business activity.

c) Training for Correct Operation of Machines For farmers or contractors who operate or use mechanical threshers or combines, special in-service-training workshops and courses should be provided by government, machinery companies and technical assistance groups. Users should be taught how to make proper adjustments and operate each machine correctly to minimize grain loss and kernel damages.

d) Animal Mowing Implements Sickle cutting is extremely slow for grain crops and even less productive for mowing grass. The lack of an effective and reasonably priced method of mowing has discouraged hay-making and the proper feeding of animals during the dry season. A simple but efficient way of cutting grass with animal power is needed.

An animal-powered wind-rower or grain swather would help larger farmers to avoid weather hazards, animal, bird and rodent attacks and to increase production of high yielding varieties of small grains.

Processing and Transporting with Animal Power

1) Limitations and Constraints

a) Scarcity of Suitable Wheels for Ox Carts Haynes reported that pneumatic-tired carts were built by several Nigerian Native Authority workshops in the North from old car axles and kit-bodies. These carts gave excellent service and users were satisfied with their performance but they were expensive due to limited supplies of suitable junked vehicles. Steel-wheeled carts also were built using imported wheels and axles, but they required major repairs after only 2 1/2 seasons' work. Haynes says there are three main complaints about imported carts, wheels and axles:

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[73] Shambaugh, Personal Communication, *op. cit.*

1. Talbot carts using ex-Bren gun carrier wheels were completely unsatisfactory because the wheels were too small, the body poorly constructed and the axle arrangement unsound.

2. Some wheels imported by the Bauchi Native Authority were unsatisfactory because of defective welding of spokes to rims.

3. Imported steel wheels were satisfactory for two or three seasons but it was impossible to obtain replacement bushings. Once the bushings wore away the hub and axle wore rapidly. Village blacksmiths were unable to make repairs.[74]

Alternatively, "rubber tires provide ample cushioning against shock, and trials in East Africa have shown that identical bearings last 13 times longer when rubber tires replace steel wheels. Also, firms specializing in wheel manufacture can produce rubber-tired disk wheels more cheaply than steel-rim steel-spoke types."[75]

b) High Prices of New Wheel Assemblies and Imported Ox Carts In most developing countries the demand for carts greatly exceeds the supply of scrap; and special axles and wheels, with spare parts, will be required to meet rising demands. In 1965 Haynes said, "there appears to be no hope of producing steel or pneumatic wheels for less than \$56.00 per set, with complete carts costing \$98.00 to \$150.00, depending on the quality of the body." There have been many criticisms that such prices are beyond the resources of farmers although similar prices are quoted for factory-made carts in other West African countries. In 1965 ox carts sold for \$136.00 in Senegal, and the cost of production in the NIAE factory in Gambia was \$156.40, although the carts were sold to farmers for \$128.00.[76]

c) Local Manufacture of Ox Carts and Yokes In 1968, the John Holt Agricultural Engineers Ltd. factory in Zaria, Nigeria, began to manufacture light-weight ox carts based on a design developed at the Institute for Agricultural Research, Ahmadu Bello University, Samaru, Northern Nigeria. Farmers say the modified John Holt carts are too light for rough usage and quite expensive at \$120.00. One hundred carts were produced in 1967 and another 100 in 1968, which were reported not selling very fast.

Shambaugh also has developed an improved ox yoke which is being made by a local workshop. He states, "we have not gotten the wood supply for the ox yokes all arranged yet. Interest is growing in the yoke and we hope

[74] Haynes, *Interim Report on Tests of Ox-drawn Implements as Groundnut Lifters*, p. 69.

[75] *Ibid.*

[76] *Ibid.*, p. 6.

to get 25 to 50 out in the Northern States for introductory purposes in the next few months."[77]

2) Need for Improved Tools and Practices

Animal-powered farmers want ox carts but the simplest types tried in the last decade in Nigeria, Ghana, Kenya and Tanzania have been unsatisfactory. Primary reasons are lack of suitable wheels and axle sets and the fact that village blacksmiths have inadequate facilities for repairing worn axles and bearings.

The price of imported carts is excessively high for the animal-farmer. It is doubtful that carts will become commonplace until a satisfactory, reasonably-priced unit is made within each country and properly supported with local service and spare parts. Haynes estimated the cost to build a cart in Nigeria, using duty-free imported tires and bodies built in a local factory, was $120.00 without allowing normal mark-up to distributors ($140.00 or $154.00) if made by the Native Authority workshops.

In a comparison between the standard SISCOMA ox cart and the Nigerian improved ox cart, Haynes said:

> In both cases the design load is one ton [937 kgs.] but a much higher safety factor is allowed in the Samaru design (because of the danger of loads of manure or laterite being saturated by rain), and car-sized tyres were rejected because of their load carrying capacity. A further consideration was that the rolling resistance of car tyres would be high in sand or mud and they would form deep ruts which might cause erosion. The high initial cost was also considered to be a factor against car tyres, although this could be overcome if 'faulty' tyres were available from manufacturers or if old, worn tyres could be utilized. None of the carts manufactured by SISCOMA are fitted with steel rims (which are considered desirable by the Northern Nigerian Ministry of Agriculture), and their carts at least are £10 [$28] more expensive than the target price of the Samaru design; no special provision is made for replacing worn out parts.
>
> In summary, it may be that in spite of these differences, it is conceivable that it would be cheaper and more convenient to import SISCOMA carts from western Africa into northern Nigeria rather than attempt to establish local manufacture or to import completed carts from Europe or the United States.[78]

Engine-powered Agricultural Systems

The profitable use of any improved tool or machine requires that it be used along with other improved inputs in an appropriate farming system. Such

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[77] Shambaugh, Personal Communication, *op. cit.*

[78] Haynes, *Interim Report On Tests of Ox-drawn Implements as Groundnut Lifters*, p. 73.

implements facilitate the development of the system by making it possible to apply or carry out some improved practice; doing it with more timeliness; enlarging the scope of operations; aiding the prevention of soil and crop loss or destruction; and by combining operations.

The creation of the most favorable environment for plant growth and production with the least expenditure for inputs per unit of yield gives the greatest economic return. The wise selection, rational use, full utilization, proper care and maintenance of suitable machinery will make any good farmer a better farmer. With adequate power and mechanical advantage, a farmer can utilize all available resources to the fullest extent of his management ability.

One of the major factors influencing high costs is the *under-utilization* of expensive machines and power units. Except for a few intensively operated and well-managed commercial farms, plantations and private contractors, most equipment in developing countries is not used to full capacity. *A major problem is idleness or non-productive operation.* Idle machines fail to minimize costs because overhead costs continue and must be paid; to engage in activity that brings in no return, or operates at a loss, is even more detrimental. The first task is to find more useful work for each machine and to reduce unit overhead costs. The second is to reduce non-productive work and wasteful operating. Too many purchasers and users of machinery think only in terms of plowing or primary tillage for a one-crop-a-year system. Much *more emphasis must be put on multiple-cropping and on diversification of operational tasks* to fully utilize productive machinery.

Ethiopia Mechanized Operations

Tendaho Plantations

Tendaho required one 55 to 60 hp. tractor for each 11 hectares under cultivation during its initial development and growth from 500 to 4,000 hectares in size. Since reaching the present size of over 5,000 hectares, the managers have been able to increase the amount cultivated per tractor up to 150 to 160 hectares through greater field efficiency, better operators, more level fields, fewer wet spots, and less breakage and down-time. At least 50 percent of this increase in efficiency may be directly attributed to better training and experience among tractor operators who accept greater responsibility for their machinery.

1) Machine Field Efficiency

Particularly revealing are records showing work-rates and average field capacities for various field operations during the past three years. Part of the indicated increase in efficiency is due to recognition of the importance

of tractor operator training, recognition and experience. Table IV.8 presents information on efficiency of field operations. All of the machines in Table IV.8 are powered by a 58 hp. Massey-Ferguson 165 tractor or equivalent unless otherwise indicated.

TABLE IV.8 COMPARATIVE EFFICIENCY OF FIELD OPERATIONS: TENDAHO PLANTATIONS SHARE COMPANY, ETHIOPIA 1966-1968

Field operation	Machine	Time period	Capacity 1966	1967	1968
		hours	- - hectares	- -	
Plowing (2 cm.)	4-furrow disk plow, mtd.	10	2-3	4	4-5[a]
	5-furrow moldboard plow	10	-[d]	-[d]	6-8[a]
Harrowing	No. 52 Tandem, 3 meter cut	10	8	20	20-25
Disking	M-36 wide-level, one-way (24 disk)	10	10	25	30-35
Planting	4-row unit planter, (91 cm. rows, no fertilizing or spraying)	12	8	14	20-25
	6-row planter (made from 1 1/2, 4-row machines)	12	-[d]	-[d]	35[b]
Inter-row cultivation	3-row rear-mtd. rigid-tooth cultivators	8	6	16	16[c]
	4-row mid- and rear-mtd. spring-tooth cultivators	8	8	20	20[c]
Slashing	182 cm. rotary single-blade	10	5	7-10	15
	3 meter rotary double-blade	10	-[d]	20	25
Leveling	3 meter Eve.:son land plane	10	-[e]	-[e]	-[e]
Hauling	2.5 x 3.0 x 2.5 meter high bulk trailers (crop put in bags in field)	8	-[f]	-[f]	-[f]

[a] With 10 plows, 50 ha./day during 1968 season were averaged. The MF-175 tractor is used with the 5-furrow moldboard plow.
[b] With an experienced driver and an assistant to watch the planters, up to 48 ha. has been planted in one 12-hour day.
[c] Because of the good, straight and even job of planting, 3-row cultivators in fields planted with 4-row planters, and also 4-row cultivators in fields planted with 6-row planters are used.
[d] Not in use at this time.
[e] Variable - depends on field condition and unevenness.
[f] Variable - depends on distance and road conditions.

2) Estimation of Seasonal Tractor Operational Hours

Using 1967 capacities as an average, an operational schedule was planned at Tendaho, using 30 tractors to work 5,000 hectares for the 1967-68 season. Since Tendaho has a fleet of 40 operating tractors, the remaining 10 tractors were used 8 hours per day for 100 days for odd jobs not directly related to crop production field activities such as transporting fuel to fields; miscellaneous cultivation to control weeds, and grass around roads, ditches, buildings, irrigation canals; construction of engineering

works such as irrigation bunds, leeves, roads, buildings, yards; and construction of ditches and canals.

The total estimated number of hours required for miscellaneous operations is equal to: $\frac{8000 \text{ hours}}{10 \text{ tractors}}$ = 800 hours per tractor.

TABLE IV.9 TRACTOR OPERATIONAL HOURS REQUIRED FOR 5,000 HECTARES OF IRRIGATED COTTON: TENDAHO PLANTATIONS, ETHIOPIA [a]

Operation	Number of machines	Size of machines	Capacity of machine/day	Total daily capacity	Req. no. days	Total machine hours
				hectares		
Slashing	7	182 cm.	7-8 ha.	50	100	7x10x100= 7,000
Plowing	10	4-furrow disk	4 ha.	50	100	12x10x10= 1200
	2	5-furrow moldboard	5 ha.			
Leveling	5	306 cm.	10 hr.	n.a.	100	5x10x100= 5,000
Harrowing (twice)	15	306 cm.	14 ha.	200	25	15x10x25x2= 7,500
Planting	10	367 cm.	14 ha.	140	36	10x12x36= 4,320
Cultivating (2-3 times)	4 6	276 cm. 367 cm.	14 ha. 20 ha.	56 120	30	10x6x30x2 1/2= 6,000
Transporting	10	n.a.	8 hr.	n.a.	50	10x8x50= 4,000
Estimated total number of hours required for crop production						45,820

[a] Assuming a 10-hour day.

The above figures give an average annual use per tractor for 30 tractors for field operations equal to $\frac{45,820 \text{ hours}}{30 \text{ tractors}}$ = 1,527 hours per tractor.

(13 of these tractors actually did over 2,000 hours of work each, during the season.)

3) Field Spraying

All field spraying is done by airplane on contract with Axum Air Service. The average spraying rate is 120 to 130 ha./hr. During a typical run, the pilot sprayed 260 hectares in less than two hours. The total cost per hectare for six sprays is about $36.00 per hectare: cost of the pilot and plane amounts to $2.00/ha. per application; cost of the chemicals (one pound DDT and 1/2

pound Aldrin) plus the service crew and entomologist is about $4.00/ha. per application.

4) Maintenance Policies

Only one driver is assigned to each tractor and he has full responsibility for its operation and maintenance. The use of assistant drivers was dropped, even when working 12-hour days during the peak seasons of plowing and planting, because each driver tends to blame the other for any deficiencies. The operation and maintenance of all tractors on the plantation is under the control of a farm equipment manager and an assistant. In addition, each of the five farms of about 1,000 hectares has one tractor supervisor and one field mechanic to assist with the daily and weekly maintenance schedules for all machines and to supervise their proper use in the field. All minor adjustments in the field are handled by the farm mechanic.

Every Saturday at 1600 hours all tractors are brought into each farm machinery pool and the drivers spend two hours tightening bolts, making adjustments and performing weekly lubrication services. In addition, every 150 hours, the oil and oil filter are changed; every 150 hours, the first fuel filter is changed and the second filter is cleaned (more frequently if necessary, twice a day when plowing dry soil). Daily service is done at the end of the work day when the drivers fill up with fuel, check the oil, water and tires and get machines ready for the following day.

During the 1968 season, the major machinery problems were: breakage of stay bars and hydraulic lifts; breakage of and failure of tire casings; battery failures and problems with electrical equipment.

a) Breakage of Stay Bars and Hydraulic Lifts This has been corrected by installing a new type of heavy-duty adjustable cross linkage between the drawbar arms to replace the weaker chains, pins and outer stay bars. Designed by Bob Brindley, the local Massey-Ferguson man, and Mike Harley, Tendaho Farm Equipment Manager, this new cross linkage keeps implements in place, prevents excessive swinging, increases stability, prevents damage to tires and tractors and is easy to adjust.

b) Breakage and Failure of Tire Casings After one or two seasons, rear tires tend to break in the center of the casing at the base of the lugs. Front tires develop radial cracks in the treads long before the tread is worn out, even though properly inflated and carefully operated. New tire designs are being tried to overcome these problems.

c) Battery Failures and Problems with Electrical Equipment In spite of extra care, batteries last only half the normal service life. Dust causes excessive wear of armatures, bearings and seals. One tractor is ex-

perimentally equipped with a Simms mechanical spring starter which is effective. If conversion costs were not so high for the older tractors, the managers would like to install spring starters on all diesel tractors.

Setit-Humera

1) Development

Several developments have great social and economic implications for the present and future development of the region. These developments include: new water supplies, year-round access and a proposed road and bridge.

a) New Water Supplies Ground water was successfully obtained for the first time by a German contracting firm (August Gottker Erben Co. Ltd., Dr. Erich Debe, Manager) from Asmara. Two wells were dug for the city and three for farms with depths from 40 to 120 meters. A three inch casing is used for wells up to 50 meters deep and a six inch casing for deeper wells. Price for the six inch casing, 120-meter well with pump and motor was reported to be $7,000. Lack of water has long slowed the growth of this area and newly available water resources should increase interest in systematic development.

b) Year-round Access A new all-weather, gravel air strip has just been completed 3 km. west of Humera. This will permit year-round operation and access to the area in the rainy season so that parts and other critical supplies can be delivered when the river is impassable and the older air field unuseable.

c) Proposed Road and Bridge Some consideration is being given to financing an all-weather road from Tessani to Humera, a bridge across the Tekeze River, two all-weather roads from Humera to the Angareb River, and one access road to Gondar. A final decision is pending.

2) Constraints

Some major constraints to these developments are: lack of stable markets and the rising cost of labor.

a) Lack of Stable Markets The price per quintal of grain sorghum at Asmara plummeted to a new low of $4.60 by April 1, 1968. Even though a Humera branch of the Commercial Bank of Ethiopia opened the first half of 1968, farmers could not borrow money for bags to store grain sorghum on their own farms. The drastic drop in price apparently was due to several causes: a bumper crop in Sudan in 1968; closing of the Suez Canal and loss of close European markets; lack of suitable long-term storage facilities in the area; and some buyer and money-lender price manipulation. Farmers insist that $4.60/quintal at Asmara is well below their cost of production. About two-thirds less sorghum was planted for the 1968-69 season, and probably twice

as much sesame and cotton. The governor-general estimated 40,000 hectares in sorghum and 75,000 to 80,000 hectares in sesame and cotton for 1968.

b) Rising Cost of Labor Labor cost is becoming a serious problem and forcing farmers to seek more efficient ways of seeding, weeding and harvesting crops. Farmers said one of the most critical problems is the need for a mechanical way of harvesting crops, especially sesame, to minimize dependence on manual labor. Timing is very important and if cutting is delayed more than two weeks past maturity, the sesame shatters and is lost on the ground.

Awash Valley Authority

1) Mechanized Cultivation Practices Trial

In addition to the work being done by the Awash Valley Authority, long-term experiments in the development of cultivation practices using various types of implements are being initiated by the Institute of Agricultural Research at the Melka Werer Experiment Station.

> Because of the large area involved, it is evident that mechanization will have to play a large part in the development of agriculture in the Middle Awash Valley. This is already evident not only in the large concession plantations, but also in the Awash Valley Authority Amibara Settlement earmarked for cropping by holders of small tenances. The degree to which mechanization can contribute to economic cropping will naturally depend upon the correct choice of equipment and its utilization.[79]

Chicalo Agricultural Development Unit

1) CADU Machinery Pool Services

During the 1967/68 year, the Machinery Section of the CADU Kulumsa Seed Farm sold nearby farmers the following services:

Threshing	290 hours at $ 6.00 per hour	$ 1,740.00
Combining	82 hours at $12.00 per hour	984.00
Plowing	2300 hours at $ 4.80 per hour	11,040.00
Harrowing	120 hours at $ 4.80 per hour	576.00
Other	14 hours at $ 6.14 per hour	85.96
Total	2806 hours valued at	$14,425.96

[79] Imperial Ethiopian Government, *Mechanized Cultivation Practices Trial; Project 12; Field 217; Strip: 1-30*, (mimeographed) (Addis Ababa: Institute of Agricultural Research, Melka Werer Research Station).

As of April 1, 1969, CADU has sold 301 hours of stationary threshing and 135 hours of combining, with services still being rendered. The 1969 total is expected to exceed previous records considerably.

2) CADU Implements Research Section

The collection, selection and testing of plows and harrows continues. Investigations in soil preparation by plowing, harrowing, field cultivating and special tillage practices are being intensified. Studies in harvesting, threshing, seed cleaning, grain handling and storage also are being carried out. The first progress report was received just as this report was going to press. It covers results of preliminary studies to improve transportation with better harnesses, carts, wheelbarrows, sleds and other vehicles and to reduce storage losses with airtight insect and rodent proof storages.[80]

Kenya Tractor-hire Service

During the second year of its existence, the Kenya Ministry of Agriculture Tractor-hire Service operated with a full complement of tractors and implements. Additional implements were purchased to permit field investigations of the possibility of reducing seedbed preparation costs. Most of the work consisted of primary tillage and wheat land planting. About 10 percent of the time was spent on cotton cultivation plowing and harrowing.

The success of the Kenya Tractor-hire Service (KTHS) to date has stemmed from concentrating on large-scale operations and commercial wheat production. Downing says, "the mere problem of organization and logistics for the operation of a mechanization service in smallholder areas makes economic operation extremely difficult; and such an endeavor must have other than direct economic motives."[81]

Kenya is an ideal country for operating a contracting service due to altitude variation which permits equipment to be utilized virtually all year. On the Masai Wheat Scheme, for example, harvesting, seeding and land preparation can occur simultaneously from 1800 to 2800 meters in elevation.

The Service performs all work for a flat rate of $5.60 per tractor meter-hour. This rate was calculated to cover costs and to avoid undue competition with existing private contractors. The rate appears to be a reasonable compromise which avoids underpricing the private contractors. The actual costs of operations of $5.43 and $5.15 per hour for the first and second year respectively, is based only on earned revenue per tractor-meter

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[80] B. Karlsson, *Preliminary Results of Farm Implement Research.*

[81] Downing, *op. cit.*

productive hour. Bad debts could cancel the favorable balance or result in net losses in future years. So far, the KTHS has been able to operate under a system of guaranteed payment. The only default to date has occurred because the actual hours were not verified at the job site.

Summary of Two Years Operations

In Table IV.10 are listed the expenditures and costs per productive-hour for operations conducted during fiscal years 1966 and 1967. A comparison shows wages increased by 45 percent, but with a 40 percent increase in tractor hours the actual cost per productive-hour increased only slightly. The fuel consumption increased slightly but the cost of fuels actually decreased with acquisition of facilities for bulk purchasing the second year. Depreciation dropped from 40 percent the first year to 27.5 percent of the depreciated value the second year, and will remain constant at that figure for the remaining life of the machines. The declining depreciation cost should be offset by increasing maintenance cost, as already indicated.

Miscellaneous costs, including operation of service vehicles, office and workshop overhead and *per diem* for field staff, show the biggest percentage increase. This was due mainly to the establishment of a field office and workshop plus the addition of a full complement of service vehicles.

Production per tractor-month and per year are shown in Table IV.11. While the total hours of operation increased, the productive hours per month dropped from 107 to 85 and the productive tractor-hours per year from 824 to 772. This decrease, Downing says, is the result of three factors affecting performance: over-reliance on inexperienced field supervisory staff; early and prolonged rainfall which delayed work; and political discussions which stopped field work for two weeks at the onset of the planting season.[82]

Evaluation of Equipment for Tropical Conditions

The KTHS uses standard agricultural tractors and machinery selected for durability and performance. All implements except the seed drills have met functional field requirements. However, structural and mechanical weakness has been encountered in both imported and locally manufactured equipment. Imported implements are designed primarily for land already under cultivation, whereas about 90 percent of the work in Kenya has been on previously broken lands. Field obstructions are numerous and the land surface extremely rough. In addition, locally manufactured equipment suffers from lack of engineering design and availability of quality materials.

[82] *Ibid.*

TABLE IV.10 FINANCIAL SUMMARY OF OPERATION OF KENYA TRACTOR-HIRE SERVICE 1966-1968[a]

Item	Total expenditure[b] 1966/67	1967/68	Cost per productive hour 1966/67	1967/68
	dollars		dollars	
Wages:				
Staff and operators	31,860	46,650	1.18	1.21
Diesel fuel	27,700	31,200	1.05	.81
Oil and lubricants	-[c]	5,015	-[c]	.13
Spare parts and repairs	21,100	35,250	.77	.91
Miscellaneous	10,920	24,650	.37	.64
Depreciation[d]	56,000	55,850	2.06	1.45
Total expenditures	147,585	198,615	5.43	5.15
Earned revenue	149,500	216,175		
Surplus[e]	1,915	17,560		

[a] Data abstracted from C.H. Downing, *Tractor Hire Service Report and Evaluation, Financial Year 1967/68* (mimeographed) (Nairobi: Ministry of Agriculture, 18 October 1968).

[b] Capital investment for 1966/67 was about $248,500 and for 1967/68 $213,500 after depreciating old equipment and buying additional implements.

[c] Included in figure given for diesel fuel.

[d] Includes operation cost for service vehicles, *per diem*, office operation and similar expenses not chargeable to tractor operation.

[e] A profit is not anticipated in the long run. The reduction in depreciation will be offset by increased operating costs.

TABLE IV.11 OPERATIONAL SUMMARY FOR KENYA TRACTOR-HIRE SERVICE 1966-1968[a]

Item	1966/67	1967/68
Tractor Months	300	600
Tractor Hours, total	35,317	50,849
Productive Tractor Hours	27,175	38,622
Productive Tractor Hours (%)	77	76
Hours per Tractor Month	107	84.7
Productive Tractor Hours per Month	80	64.4
Diesel Fuel Used, gallons	824	772.4
Fuel Consumed per Hour, gallons	1.22	1.26

[a] Data abstracted from Downing, *Tractor Hire Service Report and Evaluation, Financial year 1967-68.*

A broader range of equipment is needed and procurement plans include trip-beam moldboard plows, spring-tine harrows and rotary mowers. These implements will increase the flexibility of the unit and quality of work.

1) Trailed *versus* Mounted Implements

Trailed plows and disk harrows have been found superior to mounted implements for cultivation of virgin lands. Trailed implements generally are rugged and heavy, factors important in breaking new land with disk plows and harrows. Transport of trailed implements is a limiting factor; mounted equipment is more convenient for small farmer areas.

2) Seed Drills

Seed drills have been a major problem, being structurally too weak for operating on the rough seedbeds obtained the first year. Most seed drills do not have sufficient clearance between openers or vertical clearance to cope with surface trash encountered in tropical conditions. This is especially true for any type of mulch tillage equipment.

3) Implement Trailers *versus* Four-wheel Wagons

Implement trailers can be used for hauling bags from the combine, but are not economical. For extensive hauling, a 5-ton four-wheel bulk trailer would be more suitable. One tractor and two trailers could provide the hauling capacity for two combines by shuttling to the storage, leaving the load and taking an empty back to the field. With a two-wheeled trailer it is not practical to unhitch with a load. Land clearing equipment, crop driers, and seed cleaning equipment also are necessary for the continued operation of the wheat scheme. This equipment must be provided by either the Tractor-hire Service or by individual societies.

4) Moldboard Plows

The second year, six semi-mounted moldboard plows were added to the implement pool. The rate of plowing was extended from 0.2 to 0.5 hectares per hour up to a maximum of 0.6 hectares per hour by the addition of moldboard plows and a one-way disk plow. Downing says, "it is significant to note that three 41 cm. moldboards can be handled by the same tractor as readily as four 66 cm. disk plows under most conditions with a considerable increase in output."[83] The disk plow has an effective cutting width of only 23 cm. per furrow.

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[83] Downing, Personal Communication, *op. cit.*

5) Other Implements

Three new implements were purchased for trial: a Vicon broadcast seeder and fertilizer spreader; a Connor-Shea one-way disk tiller plow; and a Tyne seed drill. Three other implements used on a demonstration loan but not considered satisfactory were: a Rotensor power-driven disk tiller; a Turbotiller ground-driven rotary cultivator; and a rigid-tine chisel plow. Downing says, "unfortunately, it has not been possible to conduct thorough field trials with new implements but tests to date indicate that mechanical inputs can vary considerably."[84] He emphasizes that field trials must be increased in the interest of efficient mechanization, and recommends that controlled trials be continued.

a) Tyne Cultivator Seed Drill This machine performed very well in cloddy trashy conditions associated with newly-developed land. With staggered hoes in four ranks it by-passed trash very effectively. Further trials are needed to test the effects of deep placement of seeds planted in a dry seedbed prior to the commencement of the rainy season.

b) Rigid-tine Chisel Plow This is a useful implement capable of doing a first-class tillage job. Downing says, however, "for general work under a wide variety of conditions, a spring-cushion shank is required. Where stones and stumps are common, the replacement of shear bolts results in considerable delay and inconvenience."[85]

6) Field Capacity

The plowing rate of new lands with a 65 hp. tractor and three to four-furrow disk plow has varied from 0.2 to 0.5 hectares per hour; averaging 0.3 hectares per tractor meter-hour over 4,000 hectares per year. First harrowing of new lands with 2.3 meter implement was done at a rate of about 0.8 hectares per hour; subsequent harrowings ranged from 1.2 to 1.6 hectares per hour, depending upon local conditions, for an over-all average of 1.2 hectares per hour on 12,000 hectares. With a 3.2 to 3.7 meter seed drill, an average of 1.35 hectares was covered per hour. The second year the average plowing output increased to about 0.37 hectares per hour because of the large percentage of stubble plowing *versus* initial breaking.

The hours applied to a job are determined by taking the meter reading upon entering and leaving the field. This travel time is not charged. The

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[84] *Ibid.*

[85] *Ibid.*

percentage of productive meter-hours has varied from a low 60 percent in some small farmer areas to as much as 92 percent in large wheat areas. "Experience has shown," Downing says, "that it would be difficult to achieve the predicted 70 percent productive efficiency while working on small holdings."[86]

7) Cost of Field Operations

At a fixed charge of $5.60 per meter-hour, the cost of plowing ranges from $11.07 to $27.65 per hectare. First harrowing costs $6.91 and subsequent harrowings $3.46 to $5.19 per hectare while seeding costs $4.15 per hectare.

The uniform system of hourly rates has proven satisfactory. An hourly charge is more simple to administer and record, especially when working in fields of irregular shape and unknown size. Experience has shown that rates would have to be varied depending on local conditions. Local commercial contractors use a varying plowing rate ranging from $12.10 to $20.75 per hectare in the same locale where the KTHS has operated. These rates correspond favorably with the KTHS rate. For example, in the Lambwe Valley the local rate for breaking is $19.00 and at $5.60 per hour the equivalent hourly rate was $19.38 per hectare. At Meru the local rate is $12.10 per hectare on old arable fields and the equivalent hourly rate worked out to $11.05.

8) Limitations and Requirements

Access roads have been one of the most difficult problems in working throughout undeveloped areas. The lack of roads has contributed to high rates of machinery breakage and unforeseen delays to disrupt field operation schedules. Downing recommends that construction of farm access roads receive number one priority in all areas and become a prerequisite to opening new schemes.

The KTHS made suitable access roads in open country with disk plows and disk harrows at an average cost of $5.23 per km. However, clearing trees, removing obstructions, and filling ravines and washes requires a bulldozer; and some streams and water drainage ways require a minimum of a concrete crossing apron.

More effort must be given to land clearing to facilitate field work. Rains hamper seedbed preparation resulting in excessive time and energy inputs. Timeliness of operations, always difficult to achieve with a contracting service remains vital. Delays which carried the work into the rainy season made it necessary for the KTHS to fabricate dual wheel attachments for the tractors. Dual wheels permitted operation of the tractor whenever it was dry enough for the implements to work. In the future, Downing says, a greater effort must be

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[86] *Ibid.*

made to take advantage of the dry planting season, including the use of a hoe drill for deep placement of seed.

In the KTHS the tractor driver receives a fixed wage much lower than the high salaried contract supervisor. Downing says, "there exists such a large gap between operator and supervisor that there is no practical mobility." There is also a considerable variance in operators' ability and interest, but, Downing reports, "It is not yet possible, after two years to upgrade operators on merit." He recommends a graded system up to and including the contract supervisor and says this "would certainly provide incentive to increase KTHS productivity."[87]

Ghana Ministry of Agriculture Tractor-hire Service

In September and October, 1968, Starnes made a survey of tractor-hire pools and workshops in southern and northern Ghana.[88] In the Northern and Upper Regions, field records showed 907 motorized units. Physical inspection classified only 163 serviceable leaving 78 percent unserviceable. Most of the 744 units down for repair, however, needed parts such as tires, tubes, fan belts, water pumps, starters, generators, hydraulic pumps and fuel pumps to make them serviceable. In addition, there was a shortage of oil and fuel filters, batteries, gaskets, wheel bearings, and, grease guns. A comparison of the relative efficiency of large-scale farms with the small farmers was summarized as follows: "it is very strange, and this should give much concern, that the small farmers with 1.41 hectares per farmer cultivate more area per head than the large-scale farms with 1.13 hectares per worker in spite of the heavy outfit of the stations equipped with tractors and all other types of machinery".[89]

In visits to two regional workshops and 16 sub-regional tractor-hire pools and service shops, Starnes identified 15 major problems which must be overcome to make improvements in the present Ghana Tractor-hire Service:

1. A shortage of spare parts, hand tools, shop equipment and supplies.
2. A lack of automotive transport equipment for both supervisory personnel and movement of tractors and implements, especially for crawler units.

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[87] C.M. Downing, *Evaluation of Farm Machinery Staff Wage Structure* (mimeographed) (Nairobi: Ministry of Agriculture, January 1968), p. 4.

[88] Max Starnes, USAID Machinery Advisor, Accra, Ghana, Personal Communications, November, 1968.

[89] Ghana Ministry of Agriculture, *Statistics of Large-scale, Specialized, Institutional, Cooperative, and Young Farmers' League Farming and Service Stations*, 1965 Current Agricultural Statistics, 1965, Vol. II/C, (mimeographed) (Accra: Division of Economics and Statistics, 1966).

3. A lack of control over ordering, distributing and storing spare parts.

4. A lack of storage and local distribution of petroleum oil and lubricants.

5. Unserviceable tractors and implements estimated around 70 to 80 percent of all units in the field.

6. Large numbers of surplus drivers without tractors to operate still draw full pay. The survey indicated up to 1,200 surplus men with an annual payroll of $450,000 to $500,000.

7. Assignment of tractors to two divisions, increasing personnel, transportation and procurement problems, and effect the distribution of petroleum oil and lubricants.

8. Shortage of funds to purchase operating supplies. The MOA has a policy that payment must be made in full before work is undertaken. Many large organizations are not making advanced payments to cover the cost of work requested, such as fuel, oil, labor, transport of equipment to the job site, which must be paid for monthly. When debts become too large, commercial firms are forced to stop supplying until back accounts are settled.

9. Inadequate tires and tubes. The 1,600 new tires recently received by the MOA will equip only 400 tractors and 25 trailers. There are 400 tires for Deutz tractors on order which will add another 100 tractors to the operating fleet of 300 units already serviceable, for a total of 800 useable tractors. However, many of the 300 units now running have tires that are 50 to 80 percent worn and will not last through another season.

10. Unbalanced seasonal work schedule. Agriculture in Ghana is generally considered the only major activity of a tractor-hire service. Land clearing and road construction could be limited to the minor season to balance work loads and spread the operations over the entire year. With the development of irrigation along rivers and lakes, two or three crops can be grown yearly with the aid of lift pumps and land levelers.

11. Repair work not scheduled. Repair and service staffs should work the year-round with major repairs scheduled during the non-agricultural season. Drivers should be required to assist in servicing the tractors and implements, and to do any other essential work to improve operational efficiency. Supervision of personnel on attendance, working and timliness needs improvement.

12. Limited source of supply. About 80 percent of all agricultural implements and tractors in Ghana come from exterior sources.

13. Pay and salaries of staff. The drivers receive a fixed monthly salary. Mechanics are overworked and have little incentive to do good or prompt work. One report from the field indicated that mechanics were charging operators a fee before they would repair their tractors.

14. Soil and water conservation. Agricultural engineering specialists in soil and water conservation are needed in the mechanization program. Land is being cleared, plowed and cultivated without regard for soil conservation practices. Contour lines are not being followed in clearing and farming, and soil erosion and water wastage is evident.

15. Unauthorized work. Field surveys support MOA reports that tractors are being used for unauthorized work. In a MOA Transport and Mechanization Report for July, 1967 to March, 1968, the area was increased 100 percent for "increase in non-recorded acreage". This is land plowed for farmers but not officially reported by the operators and field supervisors.[90]

Nigeria Mechanical Cultivation

Tractor Unit Farms

As mechanical cultivation units, tractor unit farms have had many technical, staff and administrative problems. The soils of some sites selected were unsuitable. Also on the accounting side, costs of purchasing, operating and repairing machinery have increased rapidly while the value of dry land crops remained constant. The original subsidy for plowing was very high, eventually being reduced from 75 to 50 percent. Other problems have been low annual utilization, shortness of work season and a limited range of operations. Farmers need additional labor for weeding and harvesting but all laborers are busy on their own farms.

Machinery Hire Depots

The Ministry of Agriculture established pools of machinery which could be hired out to projects or to individual farmers. The Contract Cultivation Services were started in 1950 as government or quasi-government agencies with the plan they would be taken over eventually by private farmers or cooperatives. There are two areas of concern:

1) Rice Cultivation on *ɓadama*

The soil is too hard for hand-digging in the dry season, and time is too short to get the crop in hand after first rains occur. The full cost of contract work ($20.75 to $28.40 per hectare) was fully covered. After the land was plowed it was worked by hand. Most farms were well planned, favorably sited, had good management, a continuity of policy, and were concentrated for efficient use of tractors and machinery. Present service policies are to work near base, control work, collect fees and minimize difficulties.

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[90]Starnes, *op. cit.*

2) Upland Arable Cropland Cultivation

Charges are based on area rather than hour rates to benefit the farmer. The farmer is expected to stump and clear his land before cultivation.

The government should consider the economic advantages in encouraging private and cooperative contractors, whether they are subsidized or not. Apart from assistance in giving favorable loans, governments could engage the services of contractors whenever possible, especially during the off-season. To avoid competing with contractors during their formative years, government tractors should be withdrawn from areas where contracting services are being established effectively.

Complete Farm Mechanization

In the next decade, complete mechanization probably will be confined to estates and plantations producing high-value crops or bulky products such as sugar cane and fiber. Mechanization also will be used increasingly on cattle ranches where forage-making and production of livestock feed is not feasible without the use of engine-powered machinery. The mechanization of rice and wheat may take place but the development of the land must suit the available machinery. The problems of weed control over several rotations, and of harvesting crops with a minimum amount of hand labor must be solved before governments can establish viable mechanized pilot farms.

Many of the problems in a central machinery pool have their roots in established government procedures: difficulty of flexibly altering rules to meet seasonal or long-term needs; lack of mobility resulting from housing policies and payment of travel allowances; need to protect public funds by complex stores and accounting procedures; and the difficulty of paying incentive bonuses for increased productivity.

Effect of Cultivation Practices on Yield

Haynes reported that yield increases from more intensive cultivations are not always conclusive.[91] With certain soils and seasons, comparatively simple methods of water conservation can give worthwhile increases in yield. Since identical methods give useful measures of soil conservation, they should always be adopted in suitable circumstances. Haynes suggests that tie-ridging alone on ridged land may prove to be the only soil conservation measure required on sandy soils. He said that other types of cultivation made possible by mechanization (e.g. deep plowing, sub-soiling) do not appear to give sustained increased yields. Even extreme treatments, such as flat *versus* ridged cultivation, have not conclusively reduced or increased yields.

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[91] Haynes, *Papers on Agricultural Engineering in Northern Nigeria*, p. 17.

Where mechanization is introduced, therefore, the techniques should be chosen on criteria which lead to improved yield rather than yield alone (*e.g.*, timeliness of operation, weed control, control of erosion, suitability of machines, ease of harvest, etc.) and need not necessarily be the same for each crop. Haynes believes further agronomic trials of single operations will probably hinder, rather than advance, mechanization.[92]

<u>Mechanical Assistance to Hand Farmers</u>

The Bornu Complete Tillage Machine developed by Shambaugh can handle farmers tillage problems from primary tillage to final weeding of 1.5 meter high row crops. It is a very simple and rugged machine built from standard heavy-duty parts and requires very little maintenance or repairs. *It can be used to assist the hand-farmer with his bottleneck problems or it can be used to do the complete job, by adding various attachments.* It is a machine that the farmer or agricultural contractor can grow with as he expands his operations. Due to its versatility and the possibility of adding new attachments it will not become obsolete. It will do practically any tillage job the upland farmer needs at approximately one third the cost of hired hand labor. (Table IV.12)

Small Tractors for Equatorial African Agriculture

In a majority of developed countries with an advanced livestock industry, agriculture has progressed in one step from animal power to medium-size tractors. This is a substantial step which involves much more than the development and introduction of successful tractor-drawn implements. It is a social as well as a technological revolution and felt beyond farm boundaries. This step is considered too great in those Equatorial African countries where industrialization with its associated technical education, distribution systems and servicing facilities has not progressed very far. As an alternative to the establishment of commercial farms, it is often suggested that the step from muscle-power to engine-power can be achieved by replacing animal-power with a small and inexpensive tractor.

<u>Cost of Small *versus* Large Tractors</u>

A gradual increase in tractor size is desirable to permit the small farmers to match power to expanding production, but this is generally hampered by economic and technical factors. To meet all requirements, such a tractor has to be small and low in cost; but, unfortunately, small tractors are not necessarily inexpensive. Conditions have improved in the last decade and much greater value can be obtained for the small-tractor dollar. Haynes

[92] *Ibid.*, p. 18.

TABLE IV.12 COST OF OPERATION OF BORNU COMPLETE TILLAGE MACHINE: NIGERIA[a]

Overhead and Operating Costs	Cost dollars/hour	dollars/hour
Tractor driver cost per hour		0.12
Tractor costs per hour:		
MF-165 Tractor: New cost $3,640.00, CIF Nigeria		
Estimated life, 5000 hours or five years	0.74	
Repairs 50 percent of cost for 5000 hours	0.36	
Interest on investment @ 10 percent	0.36	
Fuel 3.26 liters per hour @ $0.193/liter	0.63	
Engine oil changed at 150 hours, Grease, estimated } 5 liters	0.01	
License and insurance @ $126.00 per year	0.12	2.22
Bornu Complete Tillage Machine Costs per hour:		
New cost $1010.00 CIF, Nigeria		
Estimated life, 15 years (15000 hrs.)	0.07	
Repairs, general, 1.5 percent per 1000 hours	0.02	
Complete set of earth tools each 500 hours, $61.60 CIF/Nigeria	0.12	
Interest on Investment @ 10 percent, $101.00 per 1000 hours	0.10	0.31
Average Total Cost per hour		2.65
Average Total Cost per hectare		2.15
Average pacity 1.2 hectares per hour.		

[a]Shambau , *Bornu Complete Tillage Machine*, p. 10.

compared prices of 7, 30 and 50 hp. tractors in Nigeria in 1964, as shown in Table IV.13.[93] In contrast, prices in Ethiopia in 1969 had both decreased for the small tractor and increased for the larger tractors. Part of this change is the result of increasing the power of the smaller units and adding more refinements and features to the larger tractors, along with a general advancement in prices of machinery.

It should be borne in mind in evaluating tractors by size that the small utility tractor is usually a simple model, while the larger tractors incorporate all the advanced features associated with modern farm equipment. In addition, prices vary a great deal between makes, engine types, modes of transportation and countries of origin. The small 7 hp. tractor was a rather sophisticated Japanese tiller, and the 30 and 50 hp. tractors standard English models

[93]Haynes, *Papers on Agricultural Engineering in Northern Nigeria*, Section IV, Appendix.

of Ford and Massey-Ferguson. In Ethiopia, the current prices cover larger tractors and some from Eastern Europe. Note the figures show only general trends and no direct comparisons are implied.

TABLE IV.13 ESTIMATED COST PER HORSEPOWER FOR DIFFERENT SIZED POWER UNITS

Nigeria, 1964	Approximate Cost	Ethiopia, 1969	Approximate Cost
	dollars/hp.		dollars/hp.
7 hp. Small 2-wheel tractor (diesel) (Japanese)	114.00	12 hp., 4-wheel utility tractor (gas) (Self-Helper)	62.50[a]
30 hp. Standard utility tractor (diesel) (English)	69.00	50 hp. Utility tractor (diesel) (Universal)	55.50
50 hp. Medium-size utility tractor (diesel) (English)	46.00	65 hp. Utility tractor (diesel) (Universal)	52.00
		(Massey-Ferguson)	73.80

[a]When purchased direct from factory, Waverly, Iowa, and including freight paid to Addis Ababa, Ethiopia.

Whether the basis of comparison is price per unit of usable horsepower or capital required per hectare, the smaller tractor (when sold and serviced by a dealer) is usually more expensive than the larger. Haynes points out that:

> This is due in part to the distribution costs which are an essential part of the retail price. Government officials are well aware that tractors can be imported through official agencies at far less than the local retail price but are aware, also, of the continual stream of complaints from field workers about the inadequacy of after-sales service for tractors. After-sales servicing, in all its aspects, is essential if tractors, regardless of size, are to be owned by farmers. But where small, cheap tractors fulfill the essential requirement of reliability, the sale of spares alone will not support the cost of these services and the agent has no alternative but to write-up the selling price of the tractor itself.[94]

Suitable Designs for Small Tractors

Even though a small tractor is relatively expensive in proportion to its size, a reliable unit may meet the needs of the emergent power-farmer, since his capital outlay is less and he already owns sufficient land. The useful power obtainable from a wheeled tractor is proportional to its weight, and the drawbar pull of two-wheeled types is usually too small for normal cultivations with conventional tools such as plows and ridgers.

Designers have overcome this problem by applying the power directly to the soil-working parts with and without separate drive-wheels, and a number of variations of the rotary hoe and cultivator have been produced. They are

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[94]*Ibid.*, p. 14.

suitable for use on medium to light soils; and they can perform useful cultivation on heavier soils as indicated in the following test report of a Landmaster 150 from East Africa. However, small tractors cannot be recommended for general use without providing operator training and good supporting services.

An alternative solution to the limiting factor of weight is to add the driver's weight to the tractor by letting him ride. This immediately increases the weight, complexity and cost of the machine, which must have at least three wheels (and preferably four) to remain stable and upright. The size of the driving wheels and total weight often becomes the limiting factor in drawbar pull. The designer must compromise between efficiency and cost, since a set of tires of moderate size can be as expensive as an engine.

There are many examples of tractors of this type on the American and European markets but the majority (being designed for garden, lawn, and sports field maintenance with small driving wheels and limited pull) are not rugged enough for African farm work. Haynes mentions that a large international charity several years ago attempted to introduce a special tractor for small farmers, but none of the major tractor firms with established distribution, servicing and training networks would accept a contract unless a minimum of 25,000 were ordered.[95] Smaller firms are prepared to make special machines but most lack the capital and facilities to provide essential services. One study noted that a basic tractor designed specifically for small farmers in Equatorial Africa would cost a farmer in England about $500.00 whereas the price quoted in Nigeria was $900.00.[96]

<u>Suitability of Small Walking Tractors</u>

The performance, durability, and suitability of small walking-tractors have been tested by a number of government testing units. To dispel the belief that the small tractor has no place in developing agriculture, the following report is presented.

A test of the Landmaster 150 machine was made by the Kenya-based machinery testing unit EATITU to ascertain the ability of the machine to work in East African conditions as a rotary cultivator.[97] Work was carried out on 39 different fields at elevations from 1135 to 2515 meters for inter-row and open field work under a variety of soil and climatic conditions. The report stated:

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[95] *Farm Implement and Machinery Review*, August, 1962, p.1126.

[96] Haynes, *Papers on Agricultural Engineering in Northern Nigeria*, p. 10.

[97] *Official Test Report of Landmaster 150 Rotary Cultivator*, (East African Tractor and Implement Testing Unit, NIAE, in Cooperation with Governments of Kenya, Tanganyika and Uganda).

> It proved capable of cultivating down to 23 cm. depth (measured from the cultivated soil surface) and the rate of work varied from 89 square yards per hour to 1,198 square yards per hour [83 to 1,122 square meters per hour]. The fuel consumption varied from 14 square yards per pint to 870 square yards per pint [23 to 1,720 square meters per liter], and from 1.19 pints per hour to 3.02 pints per hour [0.57 to 1.43 liters per hour].[98]

The general opinion was that the quality of work suited East African climatic conditions. African operators soon became accustomed to controlling the machine and, in most conditions, operated it without unnecessary exertion. Excellent work was done for seedbed preparation, in row-crops on fairly level land or along the contour but, on sloping land, good work was not always possible. There were no breakages or serious distortions during the test. When the machine was stripped after the test, it was found to be in good mechanical condition except for the flywheel magneto which has since been altered by the manufacturer.

Tested solely as a rotary cultivator the Landmaster 150 machine, in the opinion of EATITU,

> has a high rate of work under favorable conditions and is capable of producing a good quality of work under most conditions. It is reasonably easy to drive and to operate and has adequate power to deal with tough conditions at high altitudes. Accurate steering is not always possible in rows on sloping land, such as camber beds, and special care needs to be taken when working on bench terraces to avoid overturning.[99]

EATITU concluded that if reasonable precautions are taken to prevent flooding the engine with gasoline, if a clean and correct gas/oil mixture is used, and if the air cleaner is regularly cleaned, the machine should prove to be suitable for small farming and specialist work in East Africa. The construction of the machine appears to be sound and the rate of wear of the blades is not very high. A few minor modifications are desirable (which have been made).

An Economic Analysis of Present Farming Systems

Mechanization as an Analytical Concept

The concept of mechanization has been construed in terms of three distinct categories: hand-, animal-, and engine-powered technology. Agricultural systems have been similarly classified. The details of Chapter II clearly demonstrate that dynamic systems do not fall neatly into these categories, nor indeed can the concept of mechanization be classified with such precision. Some systems change more rapidly than others. Hand-labor economics appear to be relatively static although there is, in certain cases, a gradual movement

[98] *Ibid.*
[99] *Ibid.*

toward a form of animal-powered technology, as in northern Ghana; research and development work on animal implements in northern Nigeria will eventually affect the local hand-labor economy. In the Chilalo Awraja of Ethiopia, research is concentrated simultaneously on both improvements to animal-powered implements and a gradual introduction of engine-powered technology. Generally, there appears to be a trend in economic development toward increasing the concentration of power on the land. There is, however, evidence that economic circumstances in certain areas of eastern Africa render animal power more appropriate than engine power; such a realization by policy-makers suggests moving toward a policy of more circumspect employment of economic resources rather than retrograde policy-making.

Engine-powered commercial agriculture is unlikely to change its system of applying agricultural power. However, plantation farming and private entrepreneurial farming have many dissimilarities. In Setit-Humera there are obvious changes needed in the supportive infrastructure. These changes are beyond the economic resources of individual farmers although farmers collective appeal could result in necessary action from the government.

There are also a number of operations which cut across the defined systems: farmers carrying out contract work with oxen implements in hand-labor areas, (e.g. in northern Ghana), block cultivation tractor schemes in ox-farming areas (e.g. in Tanzania), the creation of a tractor-hire service (e.g. in Kenya, Ghana, and Nigeria).

Thus, the concept of mechanized agricultural technology, construed in three distinct categories, when transformed into active processes of economic development, broadens into six manifestations:

1. Processes of improvement
    a. In hand-powered agriculture.
    b. In animal-powered agriculture.
    c. In engine-powered agriculture.
2. Processes of transition
    d. From hand-powered to animal-powered technology.
    e. From animal-powered to engine-powered technology.
    f. From hand-powered directly to engine-powered technology.

Transition can include a reversal of these three processes of transition.

Change has a normal tendency to move from less to more sophisticated levels of technology and to involve more economic factors. As these factors are considered separately, it becomes apparent that not all are relevent in all the farming systems. When specific mechanization schemes are proposed it becomes essential to determine which economic factors are relevant to any particular proposal.

Mechanization and Agricultural Systems

One form of mechanization may be more appropriate than others to an agricultural system. Nevertheless, as a concept of mechanical assistance to production, *mechanization must be introduced either into an established system or appear as a new system.* The importance of analysis is to discern: the changes likely to occur during the mechanization process and whether these changes are likely to be acceptable to the local community; the systems in which the process may be appropriate; and the factors conducive or inhibitive to mechanization. The focus of this section is to present economic factors having an important bearing on agricultural mechanization.

Appropriateness

The Tanzanian case of moving from tractor power to oxen illustrates appropriateness of mechanization. Following a careful evaluation of the economic situation in certain areas, the Tanzanian government concluded that tractor-powered technology was inappropriate to the current level of development and reverted to a policy of encouraging oxen power. Thus, it cannot be assumed that there is a natural sequence from hand power through animal power to tractors. Conceivably, there are certain situations in which conditions are appropriate for moving directly from hand- into an engine-powered technology and still others in which any shift may be inappropriate.

In view of this principle of appropriateness the economic factors of each situation must be weighed carefully before planning a shift of agricultural power. Moreover, *a more sophisticated form of power cannot always be identified with a more advanced level of economic development.* There is a case for raising the level of power throughout the agriculture of Equatorial Africa, but *the optimum level of economic development is found in that economy which maximizes returns from its available resources. The analytical concept of mechanization as a means of increasing the concentration of power in agricultural technology, therefore, can be dissociated from connotations of achievement in economic development.* The concept leads to the conclusion that there is an appropriate level of mechanization for any given situation.

The Systems: Hand-powered Agriculture

The three hand-labor economies which have been described have certain similarities but they are obviously at different levels of sophistication. Agnalo village represents a hand-labor system in which the members of the village are fully occupied at certain seasons of the annual cycle and there is no market economy for any surplus production while the system provides adequately for the basic needs of the people. The Zuarungu district is not an area of natural abundance: there is hardship and privation in the area

even though available labor is not fully utilized. There are potential markets into which this economy could be articulated. In contrast to Zuarungu, the hand-labor economy in northern Nigeria represents an established market economy in which available labor is utilized on and off the farm according to seasonal demand fluctuations. All three of these cases demonstrate the complexity of hand-labor systems in the use of available labor and the proliferation of crops.

The scope for mechanization can be examined at two levels in these areas: first, whether mechanization is possible within the present system; second, whether an outside system of mechanized agriculture can be introduced into the present economy. One of the major factors in the latter consideration is whether sufficient land is available to facilitate the introduction of one, or a member, of new relatively extensive agricultural operations. If there is already heavy pressure on the land, it is unlikely that the displacement of a well-established population will be received without strong protest. Generally, this problem does not exist in Ethiopia and northern Nigeria but in northeastern Ghana the population of both people and animals is quite concentrated; the introduction of extensive commercial farming is likely to be facilitated only if population pressure can be relieved.

Within the present system in Agnale, animal-powered agriculture is impossible because of tsetse fly infestation. In the Zuarungu district of Ghana crop production is unlikely to be increased significantly without additional agricultural inputs of power, fertilizer, and improved seed. The hand-labor economy of northern Nigeria produces for both domestic consumption and the local market; the community is socially well-organized; the pattern of farming is a complex integrated system of many crops. There is a degree of market articulation between consumers and producers; 32.97 percent of available labor on the farm is spent in non-farm occupations, and 1.93 percent in working on other farms. *Regular cash exchange occurs for both wages and for goods; a commercial economy already exists in northern Nigeria which can facilitate future development.*

The Systems: Animal-powered Agriculture

Three cases in which animal-powered technology predominates have been considered. The Chilalo Awraja case in Ethiopia was developed in detail; observations on the work of the Christian Service Committee in northern Ghana and on the Tanzanian experience with animal- and engine-powered agriculture have provided supplementary information.

The Chilalo Awraja area is in a state of transition, a condition having an important bearing on present attitudes of the community toward agricultural innovation; change is not regarded with suspicion. This attitude can be

associated with the population composition, many of the present population's forebears migrated into the area from nearby Shoa province. New attitudes of the earlier migrant generation have been perpetuated through to the present; *with appropriate stimuli such an economy can be quickly modernized.* An increasing number of opportunities can be used for introduction and adaptation of appropriate forms of mechanized technology.

The Christian Service Committee performs a coordinating function between the various branches of the church's missionary work in Ghana. Its technological undertakings are the principal interest for this Study. The agricultural missionaries have developed a number of tools and pieces of equipment suitable to local conditions. Also, short training courses are organized for the local farming community. One objective of this missionary endeavor is to assist local farmers in re-establishing skills with animal-powered equipment.

In Tanzania tractor farming has proved inappropriate for many areas. Oxen cultivation is now encouraged by creating facilities for farmers to obtain animal-powered equipment and instruction in its use, and to establish properly equipped research and development centers. Tractors may continue to be used, but active encouragement is given only where scale and management make them appropriate.

The Systems: Engine-powered Agriculture

Engine-powered systems of agriculture have been considered under the broad categories of settlements, tractor-hire services, and large-scale commercial enterprises. These divisions are maintained in this discussion.

In the category of settlement schemes, the focus of operation tends toward social objectives of settling and changing the way of life of a group of people. The operation is expected to be economically sound but with less emphasis on profit than in commercial operations. In the Middle Awash Settlement Scheme there are two important contributions to its possible success. The first is the economic basis on which the scheme is operating, and the second is the technical and socio-economic problems of actually organizing the settlement. Because the first is favorable in the form of adequate market demand for good quality cotton, the operation economically is possible.

Tractor-hire services closely parallel the function of the block farms in Tanzania, classified as a settlement scheme, in that engine power is made available to farmers operating in a hand- or animal-powered system. The success of both tractor-hire schemes and block farms, usually subsidized by the government, depends on management and operational skills closely coordinated through sound planning. Where schemes are deficient in these elements, the records of operation have been discouraging.

In the category of large-scale enterprises, there are some similarities

in the commercial operations of Tendaho Plantations and the individual farmers in the Setit-Humera region. Both represent business organizations established for profit; failure to make adequate profits would, in the long run, lead to foreclosure. Similarly both areas were undeveloped before the enterprises were established; neither operation is completely mechanized, indeed there is substantial dependence on local hand labor.

The potential increase in production of cheap food grain (sorghum) close to an area of substantial food deficit, the production of an important export crop (sesame), and a ready domestic market for cotton are all factors which contribute to the significant economic potential of the Setit-Humera area. The technological system has been already established, but there is some fear that local initiative might be stifled as production increases and market prices tend to fall. The basic need is for development of an infrastructure compatible with potential levels of production so that production costs can be reduced as prices decline.[100]

Economic Factors

The fundamental economic factors involved in the systems are those involved directly in the production function. The method and proportions with which these factors are combined are determined by the type of technology employed and the skills of the individuals in the role of management. Technology introduces power into the system in the form of one of the levels of mechanization. Other agricultural inputs are introduced into the production function as appropriate to the established level of mechanization. These other inputs can function as substitutes or complements for other factors of production. As the level of power becomes increasingly sophisticated, a higher level of modern agricultural inputs becomes necessary to raise productivity sufficiently to compensate for rising costs of production. *This modernization process requires the farmer to have higher levels of both available capital resources and achievement in management skills.*

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"Since domestic supply of basic food grains has recently been an important problem for Ethiopia, and particularly in the highland north, the area has already made an important contribution with its sorghum. Agricultural progress in such a country is hardly compatible with local staple grain prices twice or more world levels. The large supply of sorghum, with its lowered price, should be taken as an opportunity, through efforts to reduce production and transport costs, to provide low price staple grain to our food deficit areas, encouraging possible feeding of livestock, and, hopefully, to develop export markets."

Imperial Ethiopian Government, *Report of the Survey Mission on the Agricultural Development of Setit-Humera*, p. 34.

Factors of Production

1) Land

In the cases of agricultural systems in Africa, land is not generally a scarce factor of production. Thus, production can be expanded readily by increasing the area under cultivation where appropriate technology and management skills are available, and where surplus production can be absorbed by the economy. Where land is scarce such as the Zuarungu district, increasing productivity is possible only by increasing the use of modern inputs which substitute for the scarce factor. Certain modern inputs may eliminate the problem of land scarcity by controlling disease vectors responsible for land's being uninhabitable.

There are certain sociological factors which cause land to be scarce. Village agriculture in northern Nigeria exemplifies this situation: farm families are concentrated in villages which limits land for cultivation to the maximum daily walking distance. To cultivate more land under the present sociological structure would necessitate establishment of new villages in uncultivated areas or the adoption of living in isolated homes located on the farms; such a process may be inhibited by strong sociological ties between the potential pioneer farmer and his family already established in the ways of village life.

Even where land is not scarce, the marginal costs of clearing and preparing new land for cultivation should be evaluated. Where these costs are heavy, improving the productivity of land already under cultivation may prove less costly, and, therefore, a more economical proposition than land clearance.

2) Labor

Labor is generally underemployed in African agriculture although in each of the hand-labor economies seasonal labor shortages have been demonstrated. Some form of appropriate mechanical assistance is needed to remove these bottlenecks. The case of the Tanzanian block farm scheme demonstrates how this can be achieved but the result is a shift in bottlenecks from the cultivating to the harvesting season.

In the animal-powered system of the Chilalo Awraja in Ethiopia hired labor is fully utilized only during the plowing season. *In improving the established system the farmer must give increasing attention to marginal decisions : whether increases in productivity warrant increasing the number of hired workers, and preserving more of his own time for management functions.*

The cases of engine-powered systems show no problems of labor scarcity. Labor is available as required for the Tendaho Plantations, for the private farmers of the Setit-Humera area, and for the Middle Awash Valley Settlement. However, the source of labor is an important consideration. For the Tendaho

Plantations highland workers move into the area after their own work on small family farms has been completed. Workers who supplement the settled labor on the Middle Awash Settlement also come from similar circumstances. Thus, in planning such operations it is essential to take into account the normal commitments of the labor supply to the family farm and to avoid conflicting with these.

In the case of private farmers in the Setit-Humera area the supply of labor causes competition between farmers to hire workers in preparation for the sesame harvesting on a seasonal basis to insure adequate labor during peak times. Migrant workers are aware of the situation and have organized themselves into bargaining groups.

3) Capital

Each of the cases under consideration demonstrates a critical shortage of capital. In the hand-labor economies a major consideration is whether any potential for capital formation exists. In the system represented by Agnale village, the economy is almost completely non-monetized and there are few natural resources available to make any tools. The Zuarungu district operates at a slightly higher level of economic sophistication, although still a non-monetary economy; the scope for small tool manufacture is only slightly better than at Agnale. In northern Nigeria where a monetary economy is established, a higher level of specialization in skills has developed; local blacksmiths make small tools which are purchased for money.

The slowness of capital formation is demonstrated in these cases. Credit facilities could enhance the ability of such economies to improve the quality and quantity of agricultural tools. *However, the establishment of such facilities must be accompanied by suitable facilities to repay indebtedness.* Repayment may be arranged in kind or in cash but *failure to include some provision for increased productivity to offset increased indebtedness leads to a chronic state of debt.*

The management of Tendaho Plantations is anxious to reap the benefits of potential economies of scale. An increase in the supply of capital raised by both public subscription and the Ethiopian investment agencies would facilitate the enlargement of operations. A commercial concern usually can expand provided the case for expansion is economically sound. Thus, at each increment of expansion the Plantations' management is obliged to justify its size of operation to the stock holders.

Scarcity of credit is a major constraint for the farmers of Setit-Humera. The prime need is for operating capital to ease the seasonal indebtedness which throws many farmers into debt with the agricultural merchants who are in a strategic position and are financially able to store produce, thereby benefitting from market fluctuations.

There is a strong case for improving credit facilities in all agricultural systems. In each case the cost of credit must be met out of agricultural production, but only for large commercial operators is the credit problem considered soluble because adequate evidence of profitability can usually provide an adequate case to raise additional funds. Where the operation of small, or even quite large, private farms is uncoordinated, the critical need for credit facilities can quickly throw the system into a situation of chronic debt, because of either inadequate levels of productivity or extortionate interest rates. The situation can be alleviated by government institutions providing and controlling credit facilities. However, such institutions must take a realistic view of the rural sector of the economy. The types of collateral and conditions of borrowing which can be accommodated by rural operators are different from those existing in the urban sectors with which banks generally appear more familiar.

Other Economic Considerations

1) Management

Agricultural production is impossible without some level of supervision. The individual farmer manages factors in the production function in a coordinated system in part determined by technology, and in part determining the level of technology which can be employed. As the level of technology increases the necessary skills of management become correspondingly more sophisticated, the farmer must shift his function from being a producer of power in the hand-power systems to a director of power in the engine-powered systems.

In the hand-labor economies the decision-making processes of management are largely the responsibility of traditional leaders. In Agnale basic operational decisions are made by the council of village elders. Decision-making in the cases of Zuarungu and northern Nigeria is based on the family group, in which the leader is the most senior male member of the family.

Decision-making increases in sophistication as the system is more completely integrated into a market system. Farmers in the Chilalo Awraja of Ethiopia sell produce and buy many agricultural inputs. Most farmers are small-scale managers. Technical knowledge is learned generally from the previous generation; the level of literacy for Chilalo is 7.4 percent of the population.[101] Thus the dissemination of information is not easy, although a good extension service is being developed. Many farmers are willing to accept this new form of local leadership.

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[101] Imperial Ethiopian Government, *Report on a Survey of Arussi Province*, p. 11.

The competence of a local extension service is extremely important where any form of improved mechanization is considered in an area with a generally low level of education. Well-trained extension agents can fill serious gaps in the technical knowledge of farmers *if the agents are accepted by the local community.*

Setit-Humera shows the need for a good extension service to assist in local farm management. In this area, management is generally extensively applied to both crops and equipment, but farmers are not obtaining the best use of their equipment; maintenance is poor and there are few technical services. No data are available for average operating hours for tractors; a depreciation rate of at least 20 percent per annum has been used in cost calculations. More intensive management should lead to better weed control (one major problem), improvement of yields, and higher performance from equipment. General educational standards among the farmers are low and good extension services would play an important role in improving the prosperity of the area.

The objective of the Awash Valley Authority is to provide intensive management by well-trained and experienced individuals willing to live on the Amibara Plains. Managers maintain strict control over all settlement operations.

Management of the Tendaho Plantations is intensive with both expatriate and Ethiopian personnel. Monthly cost accounting quickly reveals short term flaws in the operation and careful management control is maintained. Consequently, operating hours for tractors are high and, with increasing experience, operational capacities have been improved annually.

The importance of management skills cannot be overemphasized in the operation of tractor-hire services. The equipment is expensive and requires skills in its deployment and maintenance to avoid uneconomical use.

The block farm scheme employed sophisticated machinery in an area where farmers were unfamiliar with such a level of mechanization but the extension service personnel for this high level scheme was unable to provide sufficient, in either numbers or skill, to operate the scheme efficiently. Even with a large extension staff, the scheme affected only one percent of all farmers in the area.

2) Innovation and Entrepreneurship

Innovation is essential to economic development and is functionally close to entrepreneurship in that innovations usually are introduced into an agricultural system by entrepreneurs, although not all entrepreneurs are innovators. This interrelationship is borne out in the hand-labor economies; where entrepreneurial activities are an insignificant part of the system all recent innovations have been introduced by external agencies.

In the Agnale area innovations may be quite unsophisticated but their

effects are far reaching. The local people are generally willing to follow the suggestions of innovating missionaries. More innovation may come from a recent large influx of Nuer refugees from the Sudan who are largely cattle herders. Having moved into an area of cultivation they may create innovations in adapting to this new environment.

New developments in the Zuarungu area are largely the responsibility of the extension service. In an area of small farmers, extension officers can promote the use of more modern inputs.[102] If the area develops surplus production, innovations will be necessary in marketing excess production or using it for livestock feeding.

The Christian Service Committee also is in the position of local innovator in northeastern Ghana. The encouragement given to local farmers to use oxen has led to local entrepreneurship being established in the form of custom work by oxen owners.

Local innovation in northern Nigeria is likely to be put into practice by research and development agencies in the area such as the Industrial Development Center and the Institute for Agricultural Research. The socio-economic effect of building a trucking road to link a number of small villages to Zaria is under study by the Rural Economy Research Unit. *These villages now have ready access to a substantial year round market* except in the wet season; this innovation originated from a proposal from the Institute for Agricultural Research.

In the case of Chilalo Awraja, most significant innovations in the area have been introduced by CADU workers. There are a few local entrepreneurs who may act as catalysts in the area. Some twelve farmers own tractors and two of these have large farms of over 200 hectares. In the more sophisticated systems, innovation is an integral part of entrepreneurial activities. The conception of the Tendaho Plantations and its development as a going concern is largely the work of expatriate management. Innovation is a frequent occurrence especially in the operation of machinery and equipment. Not all executive and management staff are expatriate and the inclusion of Ethiopian employees is encouraged at these levels. Innovation becomes a joint effort of field, executive, and administrative managers.

Innovators in the Setit-Humera area are the private entrepreneur farmers, many of whom have not known more traditional ways of farming. These farmers are willing both to experiment with new techniques and to follow advice from more experienced farmers. However, the lack of any permanent titles to land tends to inhibit innovative land improvements.

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[102] The "Focus and Concentrate" Program sponsored by USAID/Ghana has enlisted the cooperation of a number of local farmers to demonstrate the results of fertilizer and improved seeds during the 1968/69 season.

Innovation and entrepreneurial activities are divided in the Middle Awash Settlement since executive and field management are physically separate. Most individuals in the entrepreneurial functions live in Addis Ababa, an arrangement which tends to inhibit a quick appreciation of the scheme's immediate problems. At the settlement, attempts of local management staff to innovate are often frustrated by a mediocre labor force.

3) Economies of Scale

The size of operation has an important bearing on the level of agricultural production in all systems. In the hand-labor economies there is little evidence of economies of scale in the present studies. However, these cases have to be considered in the context of potential change. The introduction of improved hand tools or appropriate animal-powered equipment may facilitate the cultivation of larger areas and through economies of scale, lead to significant increases in productivity and employment levels.

The Chilalo Awraja case exemplifies a fairly well-developed animal-powered system. Farms are small with a degree of fragmentation which inhibits an easy shift into engine-powered technology. At small-scale levels of operation the most appropriate innovations in mechanization are animal-powered improvements. In this way the farmers keep costs of operation low while improving farm productivity and incomes.

The problem of a satisfactory size of plot for engine-powered technology is overcome in settlement schemes by amalgamation of family plots for cultivation. Some diseconomies occur however. Despite the layout of land in large blocks, each family has its allocated area, and not all families are equally responsible. In the Middle Awash Settlement, outside labor is employed on seriously neglected plots; the cost is charged to the scheme and the responsible family penalized on a point system.

Size of operation is important in plantation farming. Costs of establishment and operation are spread over a large volume of production. The large size of Tendaho Plantations also facilitates the operation of a ginnery, and cotton lint is sold for approximately three times the market price of unginned cotton. Further economies could be realized by bulk transportation to Assab and to Addis Ababa.

The Setit-Humera area has obvious potential for economies of scale. Since land has not been fragmented into small holdings and there are no permanent titles to the land, amalgamation and farm reorganization should be an easy possibility. With such large holdings, a wide range of agricultural equipment is economically appropriate. However, there is a basic lack of infrastructure that inhibits full realization of these economies of scale.

4) Infrastructure

Economic infrastructure must be expanded to accommodate programs of economic development in different areas, otherwise the programs will be stifled. At present no economic infrastructure exists to serve the Agnale village area of Ethiopia with the exception of the mission school which includes some courses related to local agriculture. This area of the curriculum may be developed in the future. Recently, there have been discussions among the community leaders about forming a credit cooperative . Instruction, extension, and credit facilities are necessary elements of infrasturcture to facilitate significant improvements in the existing system. At Gambela there are warehouses and a quay which served the area when trade with Sudan flourished, an air strip, police services and a school. The infrastructure is inadequate, however, for commercial development of the area until effective communications with a market can be established.

In the Zuarungu area of northeastern Ghana, except for the lack of credit and inadequate schools, sufficient infrastructure already exists to support the market economy. If oxen power becomes established in the area, a training school for oxen and farmers will become essential and extension workers will also have to become skilled in ox-farming techniques.

In the hand-labor economy of northern Nigeria there is a general inadequacy of infrastructure to facilitate the introduction of improved mechanized technology. Feeder roads are lacking, although the main highway system is good. Both Zaria and Kano are on railways linking northern and southern Nigeria, but road connections with the south are poor.

In order to introduce animal-powered technology into the hand-labor economy, it will be necessary to establish training institutes for extension workers, farmers and animals. Credit facilities at present are inadequate to facilitate the purchase of such equipment.

In the Middle Awash Settlement in Ethiopia roads are generally inadequate for development in the immediate vicinity although the main highway to the market is adequate once the cotton has been hauled out of the immediate development area. The financial underwriting of the settlement is covered through the Imperial Ethiopian Government. The scheme is being expended quite gradually according to the availability of funds.

An important element of infrastructure for the development of the Middle Awash exists in the research station at Melka Werer which has significantly assisted the overall development of the area. The Station had accumulated a fund of local technical knowledge before the settlement was established, and continues to experiment with crops, crop varieties and cultivation techniques.

The size of the Tendaho operation and the availability of capital through

its co-sponsors have facilitated the creation of much vital infrastructure. The road to the main highway is not good at present, but the company and the local government authorities have a common interest in improving this situation.

Both operating and fixed capital are raised through the parent company and the Ethiopian Investment Corporation Share Company. The supply of capital is adequate but acts as a major constraint on expansion. More rapid expansion to the full concession of 10,000 hectares would allow the economies of scale to be exploited more effectively.

Experimentation is important in development of new techniques and dissemination of technical knowledge. Tendaho Plantations conducts experimental work on a small scale. The work, begun recently, has progressed rapidly since the appointment of an agronomist. Experimental work on variety and fertilizer trials, and on alternative cultivation techniques as well as the possibility of growing alternative crops, may have an important influence on development of both the plantations and general farming in the area.

As the surrounding economy adjusts to this large-scale operation, new opportunities develop for local entrepreneurs to establish service depots to serve small enterprises in the area. At present Tendaho workshops service a number of locally-owned tractors. This work could be taken over in the future by a local service depot with its main source of income from work done for the Plantations. Tendaho has enough equipment to justify a supply and service depot's being established in the area by one of the main agricultural machinery companies. In this way a local base could be established for repairs, service and supply of mechanized equipment.

The Setit-Humera case in Ethiopia exemplifies an area in which private resources are no longer adequate to maintain rapid development. Outside sources of capital are required by farmers especially for operating capital. Most farmers see this to be their major problem which has resulted in a general position of indebtedness. The larger entrepreneurs are able to avoid heavy debt by transporting their produce to Asmara where better prices can be obtained and regular bank credit is available.

Transport and handling charges are high in proportion to profits.[103] Produce must be handled twice or even three times because of the absence of a bridge over the Tekaze River and feeder roads in the area are inadequate.

All technical services to the area are inadequate. The Ministry of Agriculture is in the process of establishing an experimental farm at Humera. With the dearth of technical knowledge, there is need for much experimental

[103] Imperial Ethiopian Government, *Report of the Survey Mission on the Agricultural Development of Setit-Humera*, pp. 38-39.

work and extension service technical information. Only one service depot exists in the area for tractors from at least twelve different manufacturers. Insect attack is serious and an effective aerial spray service is necessary for the area to remain in cotton production. For those farmers with adequate supplies of capital, pest control is the single most important problem.

5) Impact on the Local Economy

The introduction and development of infrastructure to facilitate mechanized technology has a far reaching effect on the local economy. For this reason, the development of an extensive infrastructure becomes an important catalyst in the proximate local economy.

The Middle Awash Settlement has an important influence over local farmers. Although there are no small farmers growing cotton in the area, there are private farmers with sbustantial concessions of land who can make useful comparisons between their own methods and those of the settlement. Furthermore, the settlement has its own repair and service workshops, and recent plans include the establishment of a tractor service depot at the small village of Awash Station. There are now sufficient tractors in the area to warrant an equipment depot of a commercial dealer. Such a development is likely to accelerate the use of engine-powered equipment on the Amibara Plains in the future.

The first season of the Middle Awash Settlement amounted to an experimental period of considerable assistance in planning subsequent development. This performed the function of a pilot project by which experience already gained at Melka Werer Experiment Station was put into practice.[104]

The Christian Service Committee in Ghana influences the local economy through demonstrations, training and experimentation. Courses are related to immediate local problems and are taught through media designed for illiterate farmers. Experiments also are conducted on the small farm to test new crops, crop varieties, and different cultivation techniques.

The impact of Tendaho Plantations on the local economy is far reaching in the aspects of infrastructure already discussed. In addition, the training potential is significant. The local workshop training school prepares mechanics and drivers for work at Tendaho and adds to the local supply of technically-trained individuals. Well-educated local people are in management positions at Tendaho. Several of these individuals after leaving employment

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[104] The development of pilot schemes should obviously be a founding principle of settlement schemes which seems to be seldom adhered to in practice.

J. Arthur Lewis, "Some Thoughts on Land Settlement", Carl K. Eicher and Lawrence W. Witt (eds.), *Agriculture in Economic Development* (New York: McGraw-Hill Book Company, 1964), pp. 299-310.

with the Tendaho Plantations have become farmers themselves. *This potential for developing indigenous entrepreneurial talent moving out into smaller farming operations is important.*

On the other hand, the demonstration effect of such a large-scale operation as Tendaho on already established small farmers with no experience outside the traditional agriculture is probably insignificant since such a scale of operation is so far removed from any possible form of production that the local farmers may hope to practice. Thus, small farmers in the locality of Tendaho are unlikely to consider any technical emulations. However, the ability of small farmers to earn a relatively substantial cash income during the cotton picking season is an important factor in undergirding the traditional sector of the economy with prospects of a reliable source for an annual cash income. Small farmers now have cash to pay for seeds, fertilizers and taxes and, with a reliable cash income, are in a better financial position to consider purchasing improved inputs.

6) Level of Employment

Both the cases of Tendaho Plantations and Setit-Humera demonstrate the facility of large-scale agricultural systems, which use engine power only in part of the production process, to employ large numbers of hand laborers. Data on the distribution of labor employment on Tendaho Plantations presented in Table II.42 indicate that the number of workers reaches a peak around 7,000 at the height of the picking season, and there are over 300 permanent employees. The fluctuation in labor requirements is met by employing daily workers from the surrounding highland areas. Since cotton is not grown on the highland farms, there is little conflict with labor demands on their own farms. *The annual wage bill alone amounts to over $360,000, a substantial monetary boost where, until eight years ago, there were no employment opportunities.*

In Setit-Humera, with approximately 170,000 hectares of land under cultivation, there is a tremendous build-up of migrant labor. From the end of June through February there is an influx of some 60,000 workers from the surrounding communities. The area under cultivation is roughly 30 times larger than Tendaho Plantations and the employment level roughly ten times greater, thus, cultivation in the Setit-Humera area is much less intensive.

The main source of labor for the Middle Awash Settlement is from settler families. The Afars are given much encouragement although the scheme could not function without superior migrant workers whose numbers probably never exceed 500.

7) New Commerical Enterprises

Allusion has already been made to the facility of commercial enterprises to stimulate the development of economic infrastructure. *Large-scale enterprises*

command sufficient resources to play an important part in the initial economic development of a new area. In the hand-labor economies, commercial enterprises, particularly in conjunction with carefully planned government development programs, can help significantly in the introduction of an improved mechanized technology.

The agricultural potential of the Agnale region of Ethiopia is good, but experimental work will be necessary. There is much swamp which, with proper water control, could produce rice and cotton. Maize and sorghum grow well in the area and citrus fruits have good potential. A commercial operation in the area could exploit these economic potentials, and the local people could provide a reservoir of hand labor. Such an approach would gradually draw local people into a cash economy. As part of the total development program of the area, improving the local subsistence economy can continue as a function of missionary endeavor or be taken over by appropriate government services.

In the Zuarungu area of Ghana a few large commercial enterprises have been established: a meat-packing factory, a tomato-packing factory, a gravel and brick factory. These organizations can form the basis to expand market facilities for the small farm economy. Enterprises which use large areas of land cannot be accommodated in the area until pest control is undertaken to release more land for agricultural purposes.

In northern Nigeria cattle-raising enterprises could be developed in the nearby range country to augment the incomes and stimulate meat production from the Fulani herds.[105] Surplus grain crop production might be encouraged, where additional land is available, or by raising agricultural productivity in heavily populated areas, as a source of supplemental feed for the Fulani cattle.

8) The Market

The introduction of appropriate mechanized technology into agricultural systems necessitates finding an economic outlet for resultant increases in production. Therefore, export potential is an essential factor in considering the ability of any system to support mechanization schemes.

In considering export potential from an area, a distinction must be drawn between production for a domestic market and production for the world market. *The effective demand of a potential domestic market may frequently prove inadequate to support a proposed mechanization scheme. On the other hand, the economic vagaries, along with the demand for already established standards of quality found in the world market may render this an extremely difficult market to enter.*

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[105] John H. McCoy, "Modernizing the Northern Beef Industry," Consortium for the Study of Nigerian Rural Development, *Nigerian Rural Development*, Report No. 7, (mimeographed) (papers presented at the East Lansing Conference, Michigan State University East Lansing, Michigan, 1-2 May 1967), Section H.

The current lack of any adequate infrastructure in the Agnale area, and its remoteness from any large markets, make commercial operations impossible unless infrastructure can be developed with or without government cooperation. It is unlikely that the agricultural potentials of this area can be exploited simply by improving the existing system. An alternative possibility is producing certain high-value fruits, fish products, and skins through establishing cooperatives.

In the Zuarungu area of Ghana, beef fed on increased production of grain is a possibility but this will necessitate the development of commercial stock feeding. In the present social context, an independent commercial enterprise could develop this potential more readily than attempting to encourage small farmers to take an interest in stock rearing. Moreover, this possibility will only be feasible when substantial increases in the supply of land are made available through control of tsetse and black fly infestation.

The key source of income and growth for the upper four northern states of Nigeria is groundnuts.[106] "Nigeria is the world's largest exporter of groundnuts . . . . The prospects are reasonably good for Nigeria to triple groundnut production over the 1970-1985 period . . .[107] In order to exploit fully the exporting of groundnuts from northern Nigeria, much attention must be given to guide the production, processing, and exportation of the crop. The program which the Consortium for the Study of Nigerian Rural Development (CSNRD) recommends is to encourage production among a few farmers, concentrating on fertilizer use. Encouragement to expand production by raising producer prices is expected to lead to a substantial increase in the use of fertilizer, draft animals, and land under cultivation.[108] This approach would have a profound effect on the hand-labor economy of the area but infrastructure of all kinds will be necessary to realize the potential in this export crop.

Exports and imports of Arussi Province of Ethiopia (in which the Chilalo Awraja is located) are approximately equal; exporting wheat, barley, fruit and vegetables; and importing *teff*, maize, sugar and a few minor crop produce.[109] The grain crops for export could be developed but because of a sufficiency of grain crops in Ethiopia, the establishment of grain consuming enterprises is more desirable. CADU organizers are working on the possibility of developing beef and milk production.

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[106] Consortium for the Study of Nigerian Rural Development, *For the Busy Administrator: CSNRD's Main Recommendations and a Summary of Its Research Results* Preliminary Draft (mimeographed) (East Lansing: Michigan State University, January, 1969), pp. 26-7.

[107] *Ibid.*, p. 26.

[108] *Ibid.*, p. 27.

[109] Willis G. Eichberger, *Food Production and Utilization in Ethiopia*, E.C. 1958 (mimeographed) (Addis Ababa: USAID/Ethiopia, May, 1968), p. 21.

The Middle Awash Settlement will market ginned cotton in Addis Ababa in the 1969/70 season. Amibara cotton is of sufficiently high quality to warrant export but sources of average quality cotton first must be established to supply the national textile industry.

All produce from the Tendaho Plantations is exported from the area and cotton seed is exported from the country. Exportation to the world market of cotton lint from Tendaho probably will increase because of its high quality despite the readily available domestic market. This potential to export onto the world market is especially significant for developing countries which have to import substantial quantities of agricultural machinery.

Sesame is the high-value export crop produced in the Setit-Humera area and sorghum is an important food grain. Much sesame is exported from the country; only 15 percent of sorghum remains in the area. Cotton from Setit-Humera tends to be inferior to crops grown in other areas of the country but can be utilized in the Ethiopian textile industry, thereby releasing superior cotton to the world market.

Exploiting the export potential of the national economy is only one safeguard for programs which expand agricultural production. The nature of demand for the produce is another major consideration. Farm production is generally valued either in forms of local average market prices or imputed prices have been used to reflect seasonal fluctuations. An estimate of demand elasticities is also necessary if accurate estimates of income changes are to be computed before the implementation of mechanization programs. Agricultural production is very susceptible to the problems associated with inelastic demand curves, illustrated by the 1968 fall in prices for grain sorghum from the Setit-Humera area. (The situation was aggravated by the closure of the Suez Canal.)

The process of mechanizing agricultural technology involves a shift in the structure of farmers production costs. *This shift must be met by the market returns and must be accommodated in farmers' expectations of both market price and total saleable output.* Farm income may be changed by a shift in the diversification of production but it is essential that planners estimate the probable effect on agricultural income of a planned expansion in agricultural production. Farmers, in the same situation and with some notion of local market conditions, may conceive their own estimates. If there is a significant divergence between the estimates of planners and those of farmers, the scheme may fall into serious difficulties of implementation.

Level and Scope for Mechanization

In the Agnale village economy it is only possible to consider mechanization in terms of hand-powered tools. If some articulation with a market economy can be developed, then small engine-powered tools may become appropriate. The

present level of tsetse fly infestation makes animal-powered mechanization impossible. Tools presently in use are unsophisticated, and only by improving hand tools it is possible to improve labor productivity. The local agricultural missionary estimates that labor productivity can be doubled by improved hand tools. Such improvements are likely to increase the leisure of the workers unless an outlet can be found for additional production. New crop varieties also lead to increases in production. Some sort of compromise will have to be reached between increasing productivity of land and labor, the disposal of surplus, and the creation of greater periods of leisure time.

In the Zuarungu vicinity of northeastern Ghana a significant increase in farm power is required and may be obtainable through the development of mixed farming. The extension service of the Ministry of Agriculture and the Christian Service Committee are separate agencies working with local farmers to encourage the adoption of animal-powered technology. At present, however, the inadequate supply of draft animals, a general prejudice against working with cattle, and the small average size of farms inhibit the development of mixed farming.

In northern Nigeria, adequate labor is available and apparently there is no pressing need to increase the level of agricultural production. The reasons for crop failure are generally climatic rather than economic. Although the surplus of food crop production is seldom large, the bulk of exported crops is produced on a large number of small farms. The risk of food crop failure is hedged against by growing a wide variety of produce in a mixed cropping system. Many different crops and mixed cropping are two features of the system which are inimical to mechanization with either the animal- or engine-powered tools. *For cultivation with equipment more sophisticated than hand tools, individual crops must be grown in separate areas; thus under the present crop practices, the scope for improved mechanization must remain at the hand-tool level.*

There are, however, in northern Nigeria a large number of mixed farms which use animal power. Laurent estimates over 36,000 such farms exist in this area.[110] In addition, useful research in developing and testing new animal equipment and techniques of cultivation is in progress at the Industrial Development Center, Maiduguri. The use of ridges may be open to re-examination in the light of new developments in animal implements.[111]

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[110] Laurent, *op. cit.*, p. 235.

[111] Recent evidence suggests that the cultivation on ridges is less protective against erosion than flat cultivation. It is necessary to continuously reappraise established systems of tillage in the light of new technical knowledge. Another example of this continual necessity for experimentation is the development of minimum tillage techniques in East Africa after many years of cultivation by the disk plow practiced by European settlers.

Thus, the dissemination of agricultural technology employing animal power in northern Nigeria is feasible with the present level of accumulated technical knowledge and the presence of advisory workers in the area. However, the average farm size (2.36 hectares) and the degree of fragmentation will have to be modified before oxen power is economically feasible. A land market exists so that amalgamation and enlargement is not an impossibility. However, incentives to produce marketable surpluses must be continually reassessed so that raising productivity through improved mechanization remains attractive to the small farmer.

The Zuarungu area of Ghana is essentially a hand-labor economy. The level of animal power currently encouraged by the government does not seem appropriate to this area for a number of reasons: the officially preferred tools are too large for local oxen to pull; the local average farm is smaller than the optimum size which has been suggested for oxen cultivation (an average of 4.05-6.07 hectares to make an oxen team worthwhile contrasted with an average of 3.23 hectares per farm); the area is already heavily populated and heavy draft animals cannot be supported even if the local people could afford to buy them (which is unlikely); the disinclination of the Kusasi people to take care of oxen in a manner appropriate for draft animals.

Tests with animal power are being conducted to meet local problems. As farmers show interest, they are encouraged and given adequate instruction in new techniques with their own animals without any attempt to discourage the use of the heavier and sophisticated animal-powered equipment sponsored officially. With local population pressure, some investigations into the possibility of using small engine-powered hand equipment is needed. Such a form of mechanization could relieve progressive farmers of the necessity to house and feed extra draft animals and still increase mechanical assistance. However, serious disadvantages also emerge in considering the use of this type of engine power: repair and maintenance services become necessary; the farmers become involved in higher cost structures; the level of sophistication may move beyond the farmer's comprehension.

Ox-powered farming has generally proved adequate for domestic needs of the Chilalo Awraja area of Ethiopia. However, many obvious economies can be derived from improvements to animal implements. Local farmers are also showing increasing interest in engine-powered cultivation and are either willing to hire tractor services or seeking ways to own tractors. The possibility of engine-powered technology, however, involves the principle of appropriateness. Such technology greatly increases both the productive capability of the farmer and the total cost structure of the farm. In order to make the use of tractor power economical, the level of production must increase sufficiently to meet the increase in costs. Yields can be increased by varietal improve-

ments, fertilizer application, and the better cultivation practices facilitated by the engine-powered equipment.

As the farmer employs more sophisticated power in his farm organization, the rudimentary market also must be capable of expansion to accommodate a new level of production. *Farm structure must be sufficiently flexible, through amalgamation and consolidation of fragments, to facilitate the use of improved animal implements or tractor power.* Otherwise, the farm system cannot adjust to enable production to accommodate the new cost structure.

In the Middle Awash Settlement engine power is employed in early clearing, cultivation and irrigation pumping. Until hand labor becomes more expensive, the other operations are unlikely to be mechanized. The settlement area offers scope for large-scale testing of tools and cultivation techniques for which the Melka Werer Experiment Station can provide the necessary facilities.

Mechanized operations similar to those of the Middle Awash Settlement exist on the Tendaho Plantations and in the Setit-Humera area. Engine power insures timely and satisfactory cultivation and a well-established crop. The systems are already established and there is scope for improvement of operations and in reaping the benefit of potential economics of scale. It is unlikely that other operations will be mechanized unless new bottlenecks in the productive process emerge. The present level of available hand labor and the employment capacity of Tendaho Plantations, drawing large numbers of people into the money economy, suggests that more extensive mechanization would be inappropriate. A system of tillage using the wide one-way disk has been developed by the farmers on Setit-Humera, but there is no evidence that this is the most appropriate form of cultivation. Mechanization is likely to develop as individual farmers find new implements necessary, and manufacturers are able to bring them into the area along with appropriate services. Testing equipment brought into the area could be an important function of the experimental farm but the individual farmer looks to the government to provide such a service. The shift in total annual costs of production is an important consideration in agricultural mechanization. *For the small farmer using oxen, the total annual costs for farm power are maintained at a low level, relative to engine-powered technology.* In addition, the farmer using oxen is not required to be as highly skilled in management ability; his repair bills and cash payments are relatively low; oxen provide manure and ultimately meat; and a team of oxen can be divided into two units. On the other hand, compared with tracotrs, oxen tend to be slow; timeliness becomes more difficult, and the health of the animal bears directly on its ability to work. *Thus the low total costs of production associated with oxen power are generally accompanied by lower productivity.*

Associated Social Factors

The social system of the Agnale village area consists of small isolated village communities. Isolation is not physical since local villagers come into frequent contact with each other; but there exists a mutual mistrust among the communities tending to keep them apart. Marriage between individuals of different villages takes place, but otherwise there are few interests outside one's own village. Innovators can work with relative ease with the members of separate villages. In the future, outside commercial enterprises may attempt to operate in the area on the assumption that local hand labor can be hired from the villages, *but first this attitude of isolation, and sometimes hostility, must be overcome.*

The social structure in the Northern and Upper Regions of Ghana is composed of separate compounds; the concept of a village community does not exist. Individual members of each compound are not isolated from neighboring compounds and, there is considerable association and mutual assistance between compounds. Thus, it is possible for extension workers to operate fairly freely with groups of farmers representing a fairly wide area.

Sociological problems emerge, however, from suspicion between farmers when one, or some, appear to be prospering compared to the general performance of farmers in the area. Extension workers have found themselves involved in conflicts arising out of this situation after having selected some of the better farmers as models for demonstrations.

Developing the area by using commercial enterprises as economic catalysts will probably lead to more sociological problems, associated with the hire of labor. The ties of the land are strong in these areas of Ghana and for certain individuals to make the transition to the status of landless laborer is culturally difficult.

The introduction of tractors into the agricultural technology of an area has an important influence on the pattern of employment. One tractor requires the services of a driver, mechanic, clerk, assistant driver, and storekeeper. *Employment of oxen involves less proliferation in employment but the important aspect of the shift from oxen to tractor power is the concomitant shift in employment from uneducated to educated skills.* The effect in the short run can lead to additional unemployment of rural workers accompanied by a scarcity of educated rural workers. In the longer run, with the education of rural young people, such a shift may offer attractive rural employment to educated rural youths and mitigate the problem of migration to the cities.

The objectives of the Middle Awash Settlement will eventually lead to a dramatic modification of the Afars' mode of living. This will not be an easy task but there are sociological pressures on the Afars in this region which make conditions more favorable to change than in other parts of Ethiopia. An

important principle of settlement emphasized be Lewis has been adhered to in this scheme:[112] there must be no large capital expenditure on dwellings for the settlers. Here, the villages consist of traditional Afar houses. The place for settlement seems to be right, since the Amibara Plains has not been previsouly settled, and no local prejudices exist against settling there.[113]

Social tensions between Afar and highland people have been kept to a minimum although the obvious superiority in the quality of work done by highlanders has led to a certain amount of jealousy on the part of the Afars.

The key to the social problems of settlement in this area appears to be whether the Afars are willing to accept the advantages that accompany a cash income. Against these advantages are disadvantages of conflicting loyalties: between their former nomadic way of living with the controls of traditional leadership on the one hand; and the new way of living within the framework of the modern economy with its accompanying economic controls on the other.

The establishment of the Tendaho Plantations in a relatively isolated part of the country has initiated a number of socio-economic problems. The major problem is associated with the establishment and expansion of a local community of workers in the village of Dubte. The rapid expansion of these communities has created difficulties in accommodation, sanitation, civil administration, and domestic supplies. These are problems which are not the responsibility of a commercial organization and yet cannot be ignored. The social organization of these temporary villages may have to become the joint responsibility of the local administration and Tendaho Plantations.

In addition to this problem created by the workers, the Plantations' authorities have had to be very diplomatic with Afar leaders. Although the cultivated area is a land concession, Afar herds and flocks have always been grazed in these areas. So far, grievances have been settled through amicable negotiations with the Sultan.

There is one overriding sociological factor which has to be taken into account in all programs of economic development in Equatorial Africa: *the precedence of family loyalties*. In the social milieu of Equatorial African civilization, individual loyalties to the family and the local community have taken precedence for many generations. This acts as an economic and social security for the family and the local community. Such attitudes remain with the individual even when he moves away from the social environment of his parents or ancestors.

The demands of the modern economy come into conflict with these attitudes of social loyalty. The market economy demands a form of loyalty between the

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[112] Lewis, *op. cit.*, p. 302.

[113] *Ibid.*, p. 300.

parties in a contractual relationship; the administration of business and government demand individual identification with the rational precepts on which the institution is founded. In the final analysis, individual attitudes necessary for the successful operation of modern economics units at present are frequently in conflict with individual social attitudes and, for this reason, many apparently economically well-founded operations fail to realize their potential. Such attitudes may well change in time as several generations of Africans who understand the function of rational precepts in society, are able to build into their own social system generally acceptable provisions for economic and social security. Until such changes take place any program of economic development in Equatorial Africa must give recognition to the fact that the final loyalties of most involved individuals have terms of reference which lie outside the immediate ramifications of the program. Given such recognition, the realization that personal objectives are not identifiable completely with the objectives of a development program should not come as a surprise to planners. *Rather, personal objectives should be recognized as legitimate factors to be taken into account in drawing up development programs.*

CHAPTER V

INTRODUCTION OF IMPROVED TECHNOLOGY AND POWER INTO PRESENT FARMING SYSTEMS

Introduction: Regional Cooperation and Increased Facilities for Production

The materials in this final chapter are arranged similarly to Chapter IV. The general engineering and technical aspects of introducing improved technology and power into present farming systems are given first consideration; factors which favor the different levels of mechanization and transition from one form to another have been drawn together in the fourth subdivision of the chapter. An economic appraisal of major considerations to be taken into account when introducing new technology into a farming system concludes the chapter.

Regional Cooperation

Throughout Equatorial Africa much thought and attention is being given to the problems of introducing improved tools, implements, power units and techniques into developing agriculture. Two areas of focus are regional cooperation and increased facilities for production.

In East Africa a Specialists Committee on Agricultural Machinery meets every other year to exchange ideas and to coordinate research, education, manufacturing, testing, development and application programs aimed at solving common problems in the mechanization of agriculture. The areas most often mentioned as needing attention are: training of operators and farmers; selective and rational approaches to mechanization; adaptive research on practical farm problems; greater support by governments and agricultural extension services in demonstrating and promoting improved cultivation practices; increased emphasis on maintenance, spare parts and supporting services; more realistic and accurate cost analyses; improved efficiency in management; and the need for better planning, organization and evaluation of mechanization projects and training programs.

An overall approach is essential for all groups engaged in research, extension, education and industry to assist the small farmer to become a more efficient producer. The East African Agricultural and Forestry Research Organization has a full time staff member assigned to work with Kenya, Tanzania and Uganda in promoting and coordinating activities related to agricultural mechanization. With formation of the new East African Community and the application of Ethiopia, Zambia, Somalia and other countries to join, there is hope that regional cooperation will increase.

In western Africa groups are working separately on problems of mechanization in their respective countries; but little regional cooperation exists

at this time.

In Nigeria, an association of Agricultural Engineers has been meeting annually since 1963 to discuss progress and developments in animal- and engine-powered agriculture. Meetings are sponsored jointly by the Institute for Agricultural Research, Ahmadu Bello University at Samaru and the Ministry of Agriculture, Northern Nigeria, Kaduna. The new International Institute for Tropical Agriculture at Ibadan, sponsored by the Ford and Rockefeller Foundations, provides a base for a greatly expanded program of African regional cooperation and development.

In Ghana, the first Agricultural Mechanization Seminar was held in November, 1964, and a second meeting was held in January, 1969, to review the many problems and opportunities facing the government's mechanization program and tractor-hire service, both of which need sound business and economic bases.

In Senegal, the Bambey Centre for Agronomic Research has conducted extensive studies on animal-powered techniques and equipment and has assisted the government agricultural popularizers in putting research recommendations into effect on farmers' fields. They have also helped the SISCOMA factory to produce implements suitable to farmers' needs.

In Ivory Coast, a government-owned but privately-operated organization called Motoragri has been given the responsibility of developing agriculture and rural communities. A large part of its work is land-clearing for commercial crops and construction of roads, dams and villages. It also conducts a regular tractor-hire service for seasonal agricultural operations to assist both small and larger farmers. It works closely with the Ministry of Agriculture and the Institute for Research in Tropical Agriculture (IRAT) to develop high potential land and to introduce improved practices, techniques and implements to farmers.

Increased Facilities for Production

Considerable investment has been made to improve means of production in each of the Equatorial African countries covered in this Study. Not all investments have been wisely undertaken or effectively carried out. A few have fulfilled the hopes of the planners. Two which have been very successful, the Motoragri operation in Ivory Coast and the Narosurra Farm Mechanization Training Scheme in Kenya, will be reviewed briefly.

A great deal has been learned, but in general the small farmer has not yet benefited in proportion to the effort and money expended. While non-African commercial farms have accounted for most of the past investment in power systems for production, the smaller African farmers are now beginning to demand access to improved machinery and training, either through direct

acquisition or service rendered by government and private contractors.

Lewellyn-Jones stated that in 1967 approximately 3,000 tractors and associated equipment had been sold in the private sector of East Africa, with a monetary investment of between 10 and 11 million dollars.[1] Currently, about 30 percent of new tractors sold in Kenya are purchased by Africans. Because the Government of Tanzania terminated the tractor-hire service formerly offered through the cooperatives (230 tractors in the Western Region were sold to farmers in October, 1968), most of the tractors purchased from now on will be privately owned. In Ethiopia there has been a large increase in the purchase of tractors by private farmers; only a few have been acquired by government organizations. Sales of farm tractors jumped from less than 100 each year prior to 1965, to 172 wheel tractors in 1965; 449 in 1966; 405 in 1967; and to over 500 in 1968.[2]

In Nigeria, sales of tractors and machinery has been stalemated since the development of the Biafran situation, but a big boom is expected when the conflict ends. The government also hopes to sell some of its Ministry of Agriculture tractors to private farmers and farm contractors.

In Ghana, the Ministry of Agriculture is putting the last of its wheel tractors, purchased from Czechoslovakia before 1966, into operation in the tractor-hire service. A few private farmers, cooperatives, and plantations are beginning to purchase tractors, but the economy is still unsettled and finances tight.

In this chapter several examples will show different approaches to the problem of introducing agricultural mechanization to Equatorial African nations.

Hand-powered Systems

Improve Hand-powered Agriculture and Make the Cultivator-owner a More Efficient Producer

Utilize Extra Available Labor and Better Hand Tools to Make Improvements in Land and Physical Facilities

1. Non-monetary investments in human thought and effort can go a long way toward raising land productivity and increasing its value. Clearing land of bushes, trees, stones and stumps will permit continuous cultivation. Hand tools used with proper planning, guidance and encouragement can accomplish much despite low cash investment.

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[1]*Minutes of a Meeting of Specialist Committee on Agricultural Machinery Held at Northern Research Centre, Tenguru, Arusha, Tanzania, October, 1967.*

[2]Major farm machinery dealers, Addis Ababa, Ethiopia, Personal Communications, October, 1968.

2. The farmer can re-form or shape land surfaces to conserve water, prevent erosion and ease tillage by: removing rocks, stones, roots and other obstacles; leveling land to spread water more evenly, reduce wet spots, and eliminate dry areas; building terraces and laying contour strips to minimize water and soil loss; lengthening and shaping fields for more efficient use of tools and reduce frequent turning; developing basic water resources, springs, ponds or small irrigation canals to store, conserve, improve or control water movement.

3. Any limited capital and credit available should be used for short-term investments in improved varieties of seeds, fertilizer, pesticides and seed treatment.

Adopt Improved Indigenous Equipment to Make Better Use of Existing Hand Power

1. If the adoption of improved tools coincides with adoption of improved cultivation practices and production inputs such as seed, fungicides, innoculants, fertilizers and pesticides, a major advance can be made.

2. Improved hand equipment must be made available and its use must be skillfully encouraged and directed.

3. Model farmers can be chosen to demonstrate recommended practices, tools and techniques to neighbors and friends.

4. Farmers should be encouraged to take part in adult training programs on how to select, make and maintain improved tools; users must learn how to handle tools and make adjustments; furthermore, they must develop constructive work habits.

Hire Development and Productive Services Using Improved Tools and Increased Power to Expand Operations and to Perform Tasks Impossible by Hand

1. Where ox teams can be hired, animal power can do pre-harvest work, help out in time of peak labor demand, or permit cultivation of available land which cannot be worked by hand.

2. Where a tractor-hire service is available and dependable, it can be utilized to make capital improvements, or to perform primary tillage or difficult operations.

3. Hiring rather than ownership is desirable, initially, to keep available cash for working capital.

4. Use may be made of short- and medium-term credit to advance the level of technical input while the capacity for repayment can be improved by crop insurance, price stabilization and market development.

Encourage Farmers to Purchase Improved Hand Tools and Hire Development Services to Overcome Labor and Management Bottlenecks to Increase Production Efficiency

1. Intensification of labor and land is reached by owning simple, basic

labor-saving and production-increasing tools such as weeders, sprayers, threshers, decorticators.

2. When marketing opportunities and financial resources permit additional production, services and tools can be hired to supplement the farmer's own system for: periodic deep plowing to turn under a heavy crop residue or green manure cover crop, or to control weeds; occasional plowing and harrowing to prepare land in time for optimum planting dates; a one-time investment in contour levees to improve field layout, water control and soil conservation; a stationary-powered thresher.

3. The hand farmer should make further improvements when markets, capital accumulation, credit service, land availability and training make it possible. Then he can invest in higher-capacity power tools, such as a pair of oxen and animal-drawn equipment or a small tractor and attachments, in addition to other non-mechanical production inputs.

Assist Farmers to Purchase Improved Animal-powered or Engine-powered Tools at the Proper Stage of Development to Intensify Farm Operations, to Expand Operations, to Perform Contract Work for Others, to Make Major Farm Improvements, or to Join in Group Development

1. The degree of success in utilizing improved tools will depend heavily upon the availability of trained and experienced people to advise, direct, service and maintain recommended tools and implements.

2. The government and private enterprise should encourage the development of proper facilities and staff to service and supply improved tools, machines and power units.

3. The national and local extension and soil conservation services should help farmers to develop full land use and a water control system based on a survey of the complete water shed to determine how water can be stored and distributed, how surface run-off can be controlled, how drainage can be improved and how irrigation can be developed.

Improve Performance of Productive Farm Operations to Increase the Efficiency of the Total Farming System

Productive farm operations can be improved when the market is adequate by:

1. Using more power and bigger tools to speed up work for more timely operations;

2. Intensifying labor and management inputs on individual holdings;

3. Maximizing the use of basic agricultural resources with increased power and improved tools;

4. Reducing labor input if wages rise by maintaining a high standard of tool operation and maintenance;

5. Hiring increased power and improved tools when they are needed and

available to supplement indigenous or farmer-owned tools and labor;

6. Selecting those tools which bring the largest return and have multiple use;

7. Timing the application of productive tools to obtain the maximum benefit from increased inputs, to lower overall costs and to reduce unit costs of production;

8. Mastering field adjustments of tools for efficient operation;

9. Properly maintaining tools to keep idleness and down-time to a minimum, and to increase field efficiency;

10. Selecting and using tools which give the greatest production control with low investment and operational cost.

Assist Farmers with Limited Cash Resources by Selected Government Programs

1. Where purchasing power of a farmer is extremely limited he is at a great disadvantage if he must pay transportation charges, government excise taxes or duty and carry his depreciation costs.

2. A different approach is needed to bring the development and production tools basic to advanced technology within reach of individual farmers. Governments, therefore, should consider the advantages of sharing the financial burden of the small farmer with a supervised credit program; providing essential technical and practical direction through a capable and adequately supported agricultural research and extension program; providing a good farm-to-market road network and communication system to support an incentive-producing marketing program; and allowing improved agricultural equipment to enter the country free of duty and import taxes.

Remedy Excessive Land Fragmentation through Social and Educational Action

Governments should:

1. Encourage the establishment of small local business and shops to create alternative jobs in industry and reduce land pressure;

2. Assist in legally expediting land rationalization and consolidation through education and due process of law;

3. Help establish production cooperatives and encourage joint enterprise combinations to foster cooperation among farmers;

4. Teach agriculture in the secondary schools to help develop a more professional image of scientific agriculture.

Improve Problem Land Presently Unfit for Agriculture

Where new land suitable for expanding current production methods is not available, marginal lands can be improved and gradually brought into

useful production by joint effort of farmers and government services.[3]

1) First Stage

Using simple local tools the farmer can clear land of brush and trees on rough, swampy or sloping land; establish improved pastures for livestock; fence herds out of cultivated lands; construct silage pits to provide dry-season feed for livestock.[4]

2) Second Stage

Using larger and more expensive earth-moving machinery, the farmer is assisted by specialized contractors to provide underground drainage to eliminate wet spots; develop irrigation facilities for specific crop production: contour and ditch to control surface drainage from seasonal rains; construct farm ponds or reservoirs for water supply; and construct bench- or broad-base terraces.[5]

A list of factors which favor the continuance of hand-powered agriculture is included in this chapter in the section following the discussion of the three farming systems.

Animal-powered Systems

Introducing, Improving and Expanding Animal-powered Agriculture

Few officials of governments realize the tremendous effort, organization, and human resources that are needed, along with physical facilities and inputs for any intensive program aimed at accelerating the development of the agricultural sector of their economies. As Hapgood and his colleagues state,

> The need for adaptive research and experimentation outside the biological field is not yet well understood by those responsible for agricultural programs in the underdeveloped countries . . . They should conduct pilot schemes and test the adaptability of ideas elsewhere for their own complex of local conditions . . . Viable solutions for a particular region can be found only by adaptive experiments in that region with careful evaluation to test the results. An important dilemma is . . . a great many things need to be done to make modern agriculture work . . . and while many of these things require, for their successful performance, administrative and organizational attention from all levels of government, the human resources available to perform all these functions are

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3 While relatively slow and ineffective, hand and animal tools can be made of local materials which are inexpensive and simple; advanced tools are expensive and generally more economically run by government services or contractors.

4 Cochrane, *op. cit.*, pp. 54 and 35 (adapted).

5 *Ibid.*

exceedingly limited, and if too much is attempted at once, nothing will be done well.[6]

. . . Productivity will, as a rule, increase more rapidly if resources are concentrated on limited regions and . . . possibly on limited numbers of people . . . Frequently those most likely successfully to adopt a package of inputs and practices yielding much higher returns will be those who have had some experience of success in the past and more than average resources to risk on 'future' innovations . . .[7]

In developing countries, agriculture is confronted with the urgency to create, from the farmer to the Minister of Agriculture, an attitude of experimentation, testing and trial, continued innovation and adaptation of new ideas. Both human and physical inputs are needed. *The optimum package is one that makes maximum use of on site available resources and provides the best compromise between potential results and the likelihood of successful promotion and effective adoption of improved practices and inputs.*

Improved tools and increased power give the farmer greater control over his production environment and make possible new forms of cultivation. Research must find profitable and acceptable alternatives to traditional practices. As Hapgood emphasizes, "sustained growth in agriculture depends on . . . a broad-based research and educational system . . . responsive to the needs of rural society."[8]

Senegal as an Example of Agricultural Intensification

An example of a program to accelerate and intensify agricultural production by introducing a package of inputs, including improved animal power and implements, is described by Bour for Senegal.[9] Recognizing the great effort involved, the need for adaptive research, the importance of an able extension service and the long-term nature of agricultural change, Senegal set up a systematic, carefully integrated and supported program. Bour states that,

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[6] D. Hapgood (ed.), *Policies for Promoting Agricultural Developments, Report of a Conference on Productivity and Innovation in Agriculture in the Underdeveloped Countries* (Cambridge: Center for International Studies, Massachusetts Institute of Technology, January, 1965), p. 23.

[7] *Ibid.*, p. 26.

[8] *Ibid.*, p. 98.

[9] F. Bour, *Definition of Intensive Agricultural Exploitation* (Abidjan, Ivory Coast: Conference on Agricultural Research Priorities for Economic Development in Africa, Institut de Recherches Agronomiques Tropical . April, 1968), p. 6.

> Research must also keep in mind psychological factors . . . in order to pick solutions that have a chance of being applied. *It is absolutely necessary that a system for popularizing the results be studied along with and parallel to the research endeavor so that the research can ultimately lead to the transformation of the working habits of farmers in an entire area.*[10]

Production of Millet and Groundnuts in Senegal

A scheme of progressive improvement was planned to change gradually the traditional agriculture into a market-oriented system. Different levels of progress were defined which could be reached by most farmers without costly investments or effort out of proportion to the increased return. On a geographic area of about four million hectares, the situation in Senegal in 1963 was as follows:

Average farm size under cultivation: 3 to 4 hectares;

Average groundnut yield: 910 kg. per hectare;

Average millet yield: 460 kg. per hectare;

Fertilizer consumption: little for groundnuts, none for millet;

Animal traction: used on 50 percent of groundnut farms, not at all millet farms.

Agricultural Research Program and Results

At this time, the government of Senegal decided to intensify the production of groundnuts and millet. Agronomic research instigated several years before had already: defined varieties with high productivity, adapted to the different zones of the region and the varying rainfall; perfected cultivation techniques and practices such as time of seeding, optimum spacing, density; defined fertilization formulae for small farmers; and determined the importance of machinery upkeep and costs of production.

Implementation Program for Ox Farming

The government planned the program in two stages. The first stage was to popularize these schemes systematically so they would be applied within four years (1963-1967) by 70 percent of the farmers on these four million hectares. The second stage was to upgrade each farm program by making livestock a permanent part of the farmer's program.

An organization which specializes in promoting agricultural development (SATEC) was commissioned to work with the research institutions and organize the popularization. Four years later men, materials, time and effort had created the needed staff shown in Table V. 1 and achieved the results in Table V. 2.

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[10] *Ibid.*, p. 1. (Italics added.)

TABLE V. 1 STAFF REQUIRED TO IMPLEMENT AGRICULTURAL PRODUCTION PROGRAM: SENEGAL[a]

Personnel	Campaign 1966	1967
Senegalese popularizers	675	695
Technicians: Senegalese	16	24
European	41	35
Engineers: Senegalese	1	1
European	15	15
Total: Implementation staff	748	770

[a]Bour, *op. cit.*, p. 4.

TABLE V. 2 RESULTS OF CAMPAIGN TO INTRODUCE IMPROVED PRACTICES, IMPLEMENTS AND ANIMAL POWER FOR GROUNDNUT AND MILLET PRODUCTION: SENEGAL 1963-1967[a]

Improved Tool or Practice	1963 Number of Units	1963 Utilization by Farmers	1966 Number of Units	1966 Utilization by Farmers	1967 Number of Units	1967 Utilization by Farmers
		percent		percent		percent
Sowing Machines	65,000	50	108,000	80	124,000	95
Hoes	20,000	15	53,000	33	80,350	55
Plows	2,400	1.5	6,100	7	14,800	17
Fertilizer	kg.		kg.		kg.	
Groundnuts	18,700	16	35,200	29	44,250	37
Millet	2,300	2.5	10,560	8	11,116	10.4

[a]Bour, *op. cit.*, p. 4.

Bour says, "barring a climatic catastrophe, an increase of 25 percent on the average of the productivity of fields planted in peanuts [groundnuts] should be achieved by the end of this year [1968]."[11]

Follow-up Program in Established Agriculture

The Senegalese government's second phase, with technical goals of intensifying and "sedentarizing" agriculture and creating an association between agriculture and livestock breeding, is now being developed in three stages.

A series of agronomic research projects initiated by Institut de Recherches Agronomiques Tropicales (IRAT) in the early 1950's on cultivation techniques,

[11]*Ibid.*, p. 5.

fertilization and implements had found that bovine traction was necessary for getting the fertilizer deep into the soil until motorization was possible. IRAT devised equipment to be used, determined the work time involved and taught farmers how to care for the animals. They also emphasized feeding natural fodder, planting fallow fields with forage crops and using the by-products of harvest.

Silvestre said, "results showed that with such a cultivation system, peanut [groundnut] yields could reach 2,000 kg. per hectare and cereal yields could be brought up to 1,500 kg. per hectare; and that it is possible in this manner not only to feed the work animals but also to feed a small herd for profit."[12] The extra meat or work animals raised on the surplus feed could be sold to supplement income.

Extension workers and popularizers find it difficult to teach all improved methods simultaneously. But from research they learned that progress factors are most successful when taught together and concentrated on farmers who already have applied simple improvements and are receptive to good practices.

The first stage utilized oxen for traction and wagons for transportation. It also introduced the use of oxen for plowing and harvesting and other animals for planting and weeding.

The second stage established a stationary agriculture by annually applying fertilizer deep into the soil of last year's fallow land with the help of bovine power. Improved animal care was also emphasized in this stage.

The third stage is the complete integration of animals and crop production. Farmers are taught the rational use of crop rotations, improved fertilization, selection and care of high-yield varieties, production of temporary pasture and planting of annual field crops.

In conclusion, Silvestre states:

> Results obtained . . . on the production level and the work time for various seasons and different crops on the basis of improved agricultural tools, supplies, etc., have made it possible to define for a typical family the maximum exploitation size possible, with optimum use of manpower, optimum profit, and optimum use of agricultural equipment.
>
> The minimum area to be exploited can be determined as a function of the profitability of a team of oxen and agricultural equipment.[13]

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[12] P. Silvestre, *The Part to be Played by Agronomical Research in the Perfecting of an Intensive Agricultural Exploitation System for Senegal*, (Abidjan, Ivory Coast: Conference on Agricultural Research Priorities for Economic Development in Africa, April, 1968).

[13] *Ibid.*, p. 4.

Ghana Proposal for Ox-training Centers

The agricultural officers in northern Ghana are acutely aware of the farmers' needs for more oxen and for training. Table V. 3 summarizes a proposal for setting up an ox-training center, including operating costs for one calendar year. Three such centers are being proposed for 1969.

A list of factors which favor the transition from hand tools to animal tools is included in this chapter in the section following the discussion of the three farming systems.

Engine-powered Systems

Ivory Coast Motoragri Operation: An Example of Implementation of a Government-sponsored, Engine-powered, Large-scale Mechanization Scheme

General and Historical Background

An account of the general and historical background of Motoragri is given in Chapter II in the section concerning Large Scale Enterprises. The following recommendations[14] were drawn up by the initial Israeli study committee as steps in the plan of operation:

1. Create a government agency to take charge of natural resources and development of agriculture.

2. Establish during the first stage, two regional stations and one central depot with workshops.

3. Establish a training center for local people to staff the organization.

4. Execute selected works and establish priorities for operation.

Main work projects were outlined: clearing of bush and forests, constructing small dams, building feeder roads and providing a tractor-hire service to do contract plowing and disking for farmers without tools. All clearing on farms less than 5 hectares and dam and road construction costs were to be paid by the government. Costs of work done by the tractor-hire service would be met by the farmers. The organization has expatriate management which is scheduled to be phased out. (Table II. 47.)

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[14] As in most other development programs, there was a difference of opinion as to how a government should accelerate agricultural development. Many agricultural officials agreed with Professor René Dumont of the National Agronomic Institute of Paris that *only after* the farmer has learned to till, weed and plant by hand, to use insecticides and fungicides, should he turn to animal-drawn cultivation and chemical fertilizers; and finally, only when high returns have been obtained with animal power and man power is scarce, should agriculture be motorized.

In general, the former colonial authorities discouraged the use of tractors. They believed that soils were too shallow for mechanical cultivation, that erosion would be severe and the fertility of soils would be rapidly depleted. They were convinced that farmers have to go through a gradual step-by-step learning process from hand to animal power before they can turn to mechanization in the modern concept.

TABLE V. 3 ESTIMATES FOR ESTABLISHING ONE TRAINING CENTER FOR OXEN: GHANA[a]

	Item	Quantity	Unit cost	dollars	
1.	Buildings[b]				
	Repairs to existing buildings			100.00	
	Watering and feeding troughs			50.00	150.00
2.	Oxen				
	Four oxen @ $100.00 each				400.00
3.	Equipment				
	Rings for nostrils	16 @	0.40	6.40	
	Ropes	50 @	0.04	2.00	
	Yokes (two 213 cm. and two 162 cm.)	4 @	4.00	16.00	
	Weights	2 @	2.00	4.00	
	Dumpy level	1 @	100.00	100.00	
	Hand level	10 @	2.00	20.00	
	Sprayer	1 @	6.00	6.00	
	Duster	1 @	3.00	3.00	157.40
4.	Tools				
	Spare plow shares	2 @	3.00	6.00	
	Manure fork	1 @	3.00	3.00	
	Oxen care	1 @	40.00	40.00	
	Five-tine cultivator	1 @	40.00	40.00	
	Wheelbarrow	1 @	30.00	30.00	
	Cutlass	2 @	0.50	1.00	
	Hoes, local	5 @	0.40	2.00	
	Rake	1 @	1.00	1.00	
	Pick axe	1 @	2.00	2.00	
	Spade	1 @	2.00	2.00	
	Shovel	1 @	2.00	2.00	
	Buckets	2 @	1.50	3.00	132.00
5.	Chemicals				
	Fertilizer, assorted	1364 kg. @	0.088	120.00	
	Seed dressing:				
	Dialdrex A	0.91 kg.	4.00	4.00	
	Dialdrex B	0.91 kg.	1.50	1.50	
	Insecticides:				
	Arkotine	19 liters	0.53	10.00	
	Gammalin A	1 pkg.	13.00	13.00	148.50
6.	Lubricants				
	Grease	2.3 kg. @	4.40	10.12	
	Oil	3.85 l. @	2.80	2.80	12.92
7.	Feeds				
	Supplementary feed:				
	Concentrates	one/day/ox @	0.10	146.00	
	Salt licks	one/week/ox @	0.54	108.00	254.00
8.	Seeds				
	Groundnuts, 1.21 ha.	55 kg.		12.00	
	Guinea corn, 1.21 ha.	27 kg.		3.00	
	Early millet or maize, 1.21 ha.	7.0 kg.		.60	
	Late millet, 1.21 ha.	7.0 kg.		.60	
	Cassava, 0.81 ha.	10,000 cuttings @ 0.10/100 cuttings		10.00	
	Seeds, assorted, 0.4 ha.			1.00	27.20
	Total Estimated Cost				1282.02

[a]Prepared by N. Yenli, Regional Agricultural Officer, Tamale, Ghana, 1968.

[b]Based on use of existing buildings suitable for a training with minimum repair.

Organization and Plan of Operation

Motoragri operations are divided into seven regions. The headquarters are located in Abidjan because of proximity to the Ministry of Agriculture and other government agencies having authority to make decisions and maintain close working relationships. Spare parts also are more readily available in Abidjan with machinery dealers concentrated there.

1) Board of Directors

Every government ministry, private enterprise, and parliament is represented on the Board of Directors of Motoragri. All final decisions must be approved by the Ministry of Agriculture. The Board of Directors delegates all managerial power to the Director General of Motoragri who has operational, technical and financial control.

2) Basic Organization

Motoragri is organized with three departments and three sub-departments:

a) Department of Works Plans and executes the work program and supervises all construction projects. It is responsible for work being on schedule, within estimated costs, and up to performance standards and specifications.

b) Technical Department Prescribes work standards, specifies and purchases all engineering and technical materials and is in charge of repairing, servicing and maintaining equipment.

c) Financial Department Keeps records of all inputs in work projects, all recurring expenses and charges these to each work project on a proportionate basis along with the calculated investment.

d) Engineering Sub-department Standard plans are used if possible and modified if necessary. Original designs are made on the basis of surveys and studies. Work estimates are prepared to establish the bases for costs and proper financial accounting.

e) Training and Manpower Sub-department Courses for schools and special training programs are prepared and conducted besides giving advice on promotion, retraining, retention and discharge of manpower recruited.

f) Supply and Transport Sub-department Moves heavy tractors, buys supplies, parts and fuel, and delivers them to field units.

Selection and Training of Staff, Incentives and Work Efficiency

1) Recruitment

To obtain qualified applicants, Motoragri screened 4,000 applicants over two years and now have about 750 trained Ivoirians working on various projects.

Each prospective employee is given a series of written and practical tests. For a mechanic Motoragri also requires a Certificat d'Aptitude Professionale. Site chiefs need a high school diploma or equivalent education.

2) Employee Training

All new employees must go through a rigorous training program off and on the job. The chief of each region makes reports on the progress and aptitude of the trainee and submits periodical reports to the Director of Training. The director helps decide whether the man is satisfactory without further training, needs more training, or is untrainable and should be discharged.

Motoragri selects 60 to 70 percent of tested applicants for training. They start with classes of 20 to 30 students, about 12 to 18 students finish. To train mechanics, for example, the course is 6 months long and covers 940 hours with emphasis on practical work. Initial training is followed by work experience on the job.

3) Trainee Evaluation

Advanced training is given to staff and employees selected for upgrading after 6 to 12 months of experience. Each man is rated from 1 to 20 on five factors. He can be promoted if he receives three or more recommendations, or be discharged after three warnings of unsatisfactory work. Ratings are given by supervisors for performance, technical ability, efficiency, conduct and cooperation.

4) Farmer Training Schools

Because many farmers have purchased tractors but do not know how to properly use and maintain them, all farmers by village or area will be invited to a Motoragri School. Courses will also be given to train village artisans and blacksmiths as mechanics. Motoragri plans to offer the first schools in 1969 during off-season work periods.

5) Incentives and Work Efficiency

Motoragri plans to use tractors productively 1,500 hours each year. This averages approximately 7 hours per day and 21 1/2 days per month for 10 months. To attain this degree of efficiency, Motoragri has found that special training and incentives are needed. Field supervisors make out reports and identify employees with outstanding abilities. Drivers are rated every 3 months and the results used to determine awards and promotions.

An operator's salary starts at $61.25 per 200 hour month with the average employee receiving $86.00. Drivers can work in the field a full 8 hours and get paid for one extra hour of equipment maintenance. A working tractor hour-meter must show the extra time spent in the field. The operator informs

his supervisor immediately if the tractor hour-meter is not working since he receives pay only for hours recorded.

Selection and Maintenance of Equipment

The Motoragri staff states that all large crawlers should have power shifts and be standardized on one manufacturer. If Motoragri had standardized, stocks of spare parts would be less, with lower investment; mechanics could also specialize on one make, becoming more skilled in repairs and service.

Motoragri pays 10-15 percent duty on parts and materials imported into Ivory Coast. Recently 100 new tractors were ordered with spare parts and low-boy tractor trailers for transport. Most needed sizes are large crawlers for forest clearing. At present they cannot effectively utilize the smaller D-4's, TD-9's and TD-15's for light clearing and agricultural tillage because there are insufficient large crawlers for heavy clearing. The 45 to 59 hp. tractors were found too small and Motoragri prefers the 60 to 70 hp. models for general farm work. They want a few large 100 hp. wheel-dozers to replace some 60 hp. crawlers, because this tractor needs less maintenance than tracks, and has greater versatility and speed.

Under tropical conditions, severe rust, mud and fine dust aggravate maintenance problems. Maintenance for Motoragri tractors and machinery is pre-scheduled on a priority basis. Every 3,000 hours each tractor is returned to the central workshop at Abidjan where it is completely torn down, serviced and repaired. Careful weekly checks are given every tractor by the Israeli supervisor and Ivoirian mechanics are assigned to each job site for maintenance work.

Contract Hire Charges and Cost Accounting

Motoragri accounts for all the direct and indirect expenses attributable to each tractor. Separate cost accounts are kept on every tractor for fuel (gas, oil, lubricants); spare parts (first year: 3-5 percent total tractor value; second year: 8 percent, third: 12 percent, fourth: 18 percent, fifth: 18 percent); repair work; depreciation (straight line 20 percent of value; the life of the tractor is based on five years or 7,500 working hours, whichever is shorter); wages for operators, mechanics and supervisors (Ivoirians); fees for expatriates (Israelis); vehicle operation; radio charges; buildings and construction; and miscellaneous. The direct expenses are accountable on the basis of actual operations; the indirect expenses are determined on an hourly basis for the total annual expenditure and are weighted according to the horsepower of the tractor.

1) Estimating Job Charges versus Actual Costs

Motoragri began contract work in May, 1966. To allow time for an actual

study of operational costs, the Ministry of Agriculture met all expenditures through December, 1966. Contract charges were set on the basis of this eight-month study. After working two and a half years, Motoragri established a firm schedule of charges (Table V. 4) for every operation on which contracts are negotiated, based on the number of hours recorded on the tractor hour-meter. Monthly estimates of expenditures are made according to projected hours to accomplish contract work. Estimates for 1967 were 1 percent different from the actual costs and 1968 estimates were expected to be even closer.

When the Director of Works receives the end-of-job notice, the quantity of work recorded is totaled, an account of the total costs is prepared and submitted to the client.

2) Operating Budget

To date, 50 percent of the budget has been guaranteed by the Ministry of Agriculture for work ordered by the Government as part of the contractual arrangement. This work is vouched for every three months by the Regional Director of Agriculture. The remaining 50 percent of work is obtained by Motoragri, subject to approval by the Ministry of Agriculture, mainly from private land holders, and large public and private companies.

Some work also is done for small farmers but those with less than five hectares each must form contiguous groups of at least twenty farms so that a minimum of 100 hectares of work may be performed in one area. Some work has been undertaken on as little as 60 hectares, depending on the distance and difficulty in transporting the crawler tractors.

The 1968/69 operation is about $4 million. The government Agricultural Bank makes some credit available for a limited number of jobs where several years may elapse before cropping can produce sufficient income for repayment. Motoragri has no difficulty in obtaining work, but problems arise over financial arrangements to prevent default or hasten slow payments. Motoragri is not empowered as a credit agency and, therefore, is unable to accept contracts without satisfactory financial arrangements.

Narosurra Farm Mechanization Training Scheme: an Example of Training Kenya Farmers to Become Skilled Tractor Operators and Better Farm Managers

This school for training young African farmers and farm managers in techniques of efficient and economical agricultural production is an excellent example of inspired, dedicated cooperative education. Men who come to this center for practical and thoughtful training are eager to learn and are enthusiastically encouraged by the largely volunteer staff.

Trainees learn to make decisions, account for costs, manage diverse operations, but primarily to handle, maintain and utilize modern tools and machines

TABLE V. 4 APPROXIMATE CHARGES MADE FOR CLEARING, TILLAGE, DAM AND ROAD CONSTRUCTION: MOTORAGRI 1968-1969

Clearing (Felling, windrowing and piling)	Cost dollars/hectare
Heavy forest	448. to 653.
Medium forest	286. to 448.
Light forest	184. to 286.
Savannah	143. to 184.
Sub-soiling (to remove roots)	49. to 82.
Agricultural tillage	
Plowing	16.30 to 24.50
Pulverizing	16.30 to 28.55
Disking	16.30 to 24.50
Cultivation or planting	7.34 to 9.78
Mowing (rotary)	6.53 to 8.98
Spraying	3.26
Roads (7-meter road surface plus 3-meter ditch)	**Cost** dollars/kilometer
Heavy forest	571. to 735.
Medium forest	490. to 571.
Light forest	326. to 490.
Savannah	204. to 326.
Ballasting and earth moving (dams and roads)	**Cost** dollars/cubic meter
Distance of transport less than 100 meters	0.61 to 1.02
Distance of transport, 100-500 meters	1.02 to 2.04
Distance of transport, 500 m. to 5 km.	2.04 to 2.65

in agricultural production operations. The three-month course is intensive and involves long hours in the classroom as well as field and laboratory work. For experience, students do contract work for farms in the neighborhood. The average day in the six-day week starts at 7 a.m. and ends at 9:30 p.m.

Course Content

Student subjects and hours devoted to each in the 12-weeks' curriculum are shown in Table V. 5.

TABLE V. 5 TWELVE-WEEK WORK AND STUDY PROGRAM AT THE NAROSURRA FARM MECHANIZATION TRAINING SCHEME: KENYA 1969

Course	- - - - - -Hours- - - - - - - - - Weekly	Course Total
Tractor maintenance	7	84
Mechanical subjects	29 1/2	330
Accountancy	3	36
Crop husbandry	1 1/2	18
Animal husbandry	1 1/2	18
Tests and final examinations	1 1/2	42
Films, debates, talks, etc.	7	84
Total hours	51	612

1) Tractor Driving

Each student receives three hours of instruction on tractor operations per week, culminating in the use of different types of implements with the tractor.

2) Mechanical Cultivation

Students are taught how to adjust common implements and given instruction on the capabilities of machines for plowing, cultivating, planting and harvesting.

3) Machinery Maintenance

Students learn basic principles about diesel and gasoline tractors; safety measures and handling; and daily, weekly, monthly, and annual maintenance services. They also learn how to make simple repairs on tractors and implements; and to make nuts and bolts.

4) Welding

Students learn simple gas welding, including sawing, cutting, welding of plates and round bars, and safety precautions.

5) Accountancy

Students learn how to read invoices, statements, receipts and bank statements; to keep and balance a cash book and bank book; to make allocations; and to do tractor and implement costings.

6) Crop Husbandry

Students are taught fundamental facts about the soil, plant foods, soil and water conservation, fertilizing, seeding, rotations, silage production and hay making.

Training Concept

With increasing Africanization of farms in Kenya and elsewhere (including the opening of vast new areas all over East Africa to commercial farming), there is a great need to provide sound training in modern farming methods. Most new African farm owners lack personal facilities or opportunities to learn these new methods. Many new owners have come from urban areas with a basic knowledge of agriculture, and with the erroneous belief that farming is easy and profitable. As a result, many Africans have started farming with great expectations and ended deeply disappointed. Potentially profitable farms have lost money as problems multiplied and production dropped. When new lands brought under cultivation fail to measure up to optimistic forecasts, the economy stumbles.

The concept behind the Narosurra Training Scheme is unique. In 1963, in northwest Kenya near Sabatia, there were 18 successful large-scale European-owned farms. In 1964, the government of Kenya, as part of the "Million Acre Settlement Scheme", bought out one after another until only Mr. and Mrs. Michael Low remained. The large farms were divided into about 650 smaller farms for Africans, averaging 12 to 20 hectares each, but with some of 40 hectares. With little equipment and few animals, most of the Africans had to borrow up to 100 percent of their finances to obtain basic inputs for farming. Consequently, new farmers lacked adequate capital, tools and crop needs. *But most of all they lacked adequate training and experience for farming.*

The Africans began to farm. They copied and they made mistakes; their land began to run down and they finally went to Mike Low for advice and help. Mike Low saw the problems and, with his wife's encouragement, conceived a plan to train local farmers in the essential subjects of mechanized farming. His plan was presented to the Ministry of Agriculture of Kenya, and while it was encouraged, it was not officially financed or sanctioned initially. Undaunted, the Lows sought and obtained support from private sources, friends and churches, and started their first class as the Narosurra Mechanization Training Scheme in 1966.

Budget and Student Costs

The proposed budget for the Narosurra school is $54,600 annually, amounting to $364 per student for three classes of 50 students each. To train one student with the present facilities, room and board, costs $140 per class, not including salaries for any of the staff. Each student is asked to pay a $70 enrollment fee. For those who cannot pay, Low has set up a scholarship fund so that no deserving student has to be turned away if class space is adequate. The reputation of the school is excellent; for the fifth class there were 130 applicants.

Beginning in 1968 the Kenyan MOA partially supports the Narosurra Mechanization Training Scheme[15] with a yearly grant of $5,800 toward the costs and salaries of instructors who previously were unpaid. The MOA has agreed also to support 60 students per year (20 students in each of three classes per year) for the next four years. These students are to be selected from all over Kenya. After successful completion of the mechanization course at Narosurra, they will be eligible for loans through the World Bank fund to buy tractors and machinery.

Quality of Training

Narosurra's objective is to train quickly and economically, African farmers to operate their own farms and/or do contract work for others. Indicative of the quality of training given at Narosurra is the fact that the 1967 Kenya National Plowing Championship was won by a man trained at Narosurra. He placed second in the World Plowing Contest held in South Africa in 1967.

Some 130 men have passed through the scheme so far. A follow-up on some graduates in March 1968 indicates the results:[16]

Mr. Kamau Mbabara has a small farm in the Cherangani hills of Kenya. He earned over $560.00 toward his tractor in the first three months of acquisition. He had requests to plow over 200 hectares for his neighbors, and has been asked to plow another 690 hectares. He is considering raising a loan for a second tractor since only one other tractor is near him.

Mr. Jacob Kigen, who attended the second course, has formed together with 30 other farmers, the Mochongoi Farmers' Group. The group has already paid 75 percent of the price of its new tractor and is planning for a second one. He says, "we aim to do high quality work. Because of this we are getting more requests than we can fulfill."

Mr. Wilfrid Tomno and Mr. Solomon Chirchir both farm in the same district. They are helping to plow 200 hectares for the Kabimoi Farmers' Cooperative Society. They hope to pay for their tractor within four years. Mr. Tomno said, "I realize that unless I can manage to plow 16 to 20 hectares of land each week in the plowing season, I will not be able to pay back my loan."

Mr. Harroson Njuguna, a graduate of the third course, does not own a farm but does contract work for Kinangop farmers. It is a large area with few tractors. He writes: "In January 1968 I achieved my target of work to the value of $357. I hope to do even better in February with over 40 hectares to plow.

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[15] The Narosurra Project also is assisted by generous donations from private individuals, the Danish Government, Oxfam, Freedom from Hunger, Christian Council of Kenya, Catholic Relief Services, Farm Machinery Distributors and others.

[16] *Progress Report Narosurra Farm Mechanization Training Scheme*, Received January, 1969, p. 12.

To reduce travel expenses, I remain in the field until each area is completed. I plan to visit Narosurra for a refresher course for a week or two during the rains." Mr. Njuguna has offered to service machines of other tractor operators in his neighborhood for a small fee.

A list of factors which favor transition from hand- and animal-powered to engine-powered agriculture is included in this chapter in the following section.

Factors Which Favor Different Levels of Mechanization

At any given time with a specific set of conditions in a particular stage of development there are many individual factors and combinations thereof which affect the adoption of a level of mechanization and its continued use. Those factors which tend to favor one form of power over another are listed below without any implication of priority.

Factors Favoring Continuance of Hand-powered Agriculture

There are many factors influencing the continuance of hand-powered agriculture:

1. Very small fragmented farms with scattered fields of odd shape.
2. Land only partially cleared and developed, with trees, roots and stumps left in place to interfere with animal- or engine-powered tools.
3. A surplus of labor during the greater part of the crop production year.
4. A high density of population to arable land which forces use of worn-out or marginal land, greater land fragmentation and subsistence-level farming.
5. Very low *per capita* income making the farmer self-reliant but unable to invest in new and income-increasing inputs.
6. Low technical ability of farmers and workers who tend not to be innovators nor to develop improved methods and tools.
7. Intensive production methods which use 2 to 8 mixtures of crops in the same field, preventing use of labor-multiplying animal- and engine-powered tools and techniques.
8. Great attachment to tradition due to isolation and the lack of educational opportunities in rural areas.
9. Conservatism of rural people who have lived at subsistence levels and are over-cautious.
10. Lack of effective demonstrations by mobile extension teams to convince farmers of the benefits of improved farming practices.
11. Existence of narrow paths and very limited farm roads that prohibit entry and movement of wheeled machinery.

12. High import prices and taxes on improved agricultural machinery and parts, making them more costly for an African farmer than for an American or European farmer.

13. Shortage of spare parts due to high wear and breakage rates, poor logistics support and inexperience in planning and maintenance.

14. Scarcity of farm machinery servicemen and mechanics because of school enrollments, low pay, and emphasis on white-collar positions and social status.

15. Lack of training centers and facilities for training farmers, extension workers, tractor operators, village blacksmiths and artisans.

16. Inadequate industrial demand for agricultural raw materials and a lack of local industries to process or utilize agricultural products.

17. High cost of locally manufactured products which are often made of inferior materials which wear out quickly.

18. Deficiency of suitable designs for machines and tools adapted to the needs of the small farmer, low cost and suitable for local manufacture and repair.

19. High prices of petroleum fuel which make transporation costs high and discourage the use of engine power for agricultural production.

20. Existence of government policies which put low market emphasis on agricultural development and over-emphasis low food prices for urban workers.

Factors Favoring Transition from Hand Tools to Animal Implements

Many factors, both in single and multiple combinations, exist to favor the transition from hand- to animal-powered implements in Equatorial Africa. The combination(s) that tips the balance to bring about change is very complex and varies between peoples, agricultural areas and countries. Without any attempt to measure or weigh individual factors or combinations, some of the most important are listed for consideration by policy makers, planners, administrators, advisors and others who are concerned with agricultural and national development and the problems of small farmers.

1. Availability of labor is a severe limitation on the amount of land that can be prepared for planting. The maximum capacity of a hand farmer (4 to 6 hectares) is less than the land area to be farmed.

2. Labor is a definite limitation in the amount of land that can be effectively weeded during the wet seasons.

3. Rising costs of hired labor make its use restricted in relation to low and unpredictable product returns.

4. Part of the traditional family labor is lost to required school attendance as educational standards and facilities improve.

5. Where new land is available, the pressing need for more food production emphasizes its development and requires additional power. Ox power is

especially suited to tropical areas of high elevation with temperate climates and more than 76 to 100 cm. of rainfall per year.

6. Where additional land is not available, population pressure and food demand force existing land to be more intensively cultivated with the aid of animal power.

7. Improved livestock production methods, including disease control, forage production, feed storage, and introduction of stronger and healthier animals, favor the use of animal power.

8. Increased local availability of improved animal-drawn tools and implements, either imported or locally made, makes farmers aware of better means. Farmers seek improved, lightweight, simple, robust and inexpensive tools.

9. The establishment of training centers to train animals and farmers introduces better harnesses and control methods along with better crop husbandry.

10. The introduction of improved cultivation practices such as row seeding, inter-row weeding, pest and disease control methods, irrigation, manuring and fertilizing encourages use of higher capacity labor multiplying animal tools.

11. The development of access roads to fields and markets encourages the development of animal-drawn wheeled transport both for field work and for transporting farm produce out and manufactured goods into rural areas.

12. The incorporation of new activities in mixed hand- and animal-powered agriculture encourages the adoption of improved practices and implements. (Examples are: introducing and improving overall water control measures; forming and shaping land to make better use of higher capacity tools; deeper plowing to exploit new levels of fertility; and more thorough tillage to permit burial of crop vegetation, green manure crops and fertilizers.)

13. The introduction of new crops with specific recommended practices either requiring or directly benefiting from the application of increased animal power and improved implements to increase environmental control or to permit expanded operations.

14. New land suitable for power methods becomes available to farmers in larger blocks than can be farmed effectively by hand (4 to 8 hectares) through purchase or reassignment of government, church, traditional or private lands.

15. A growing desire for change exists along with a willingness to try new ideas and inputs. The acceptance of one new, outstanding implement or tool paves the way for a host of further changes. LaBrousse points out that the groundnut drill in Senegal, the turning plow in India, and the ridging plow in Nigeria and Ghana sparked the advance of animal power in those areas.[17]

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[17] G. LaBrousse, *Mechanization of Agriculture for Under-developed Tropical Countries* (paper presented at Africa Mechanization Advisory Conference, Michigan State University, East Lansing, Michigan, July, 1967), p. 2?.

16. The evidence from successful animal-powered farmers or schemes within 20 to 40 km. of a hand-powered area acts as a catalyst to stimulate interest, to furnish a source of work animals, and to provide an initial supply of improved tools.

17. Where oxen or bovine traction currently is not employed, available donkeys can be drafted. Braun in Niger used donkeys without previous training as draft animals with good results in light soils and in heavier soils prepared at the right moisture content.[18]

Factors Favoring Transition from Hand and Animal Power to Engine-powered Agriculture

1. Present attainment of a basic mechanical ability by many farmers permits them to quickly become qualified machinery operators.

2. A strong desire exists among farmers for improved machinery and tools.

3. Farmers have good knowledge of cultivation techniques and ability to effectively utilize present resources but are constrained by power limitation.

4. The government is generally sympathetic and well-grounded in the fundamentals of mechanization at all levels with established, proven programs to assist the farmers.

5. Education, research and extension programs promote and support mechanization at all levels with constant movement to improve.

6. Competent agricultural technicians are available at local levels to assist the small farmer in improved farming practices.

7. Local level of supporting services for fuel and supplies are available.

8. Technical services for repair and maintenance are available at local level.

9. Feeder roads and transportation facilities from farm to market to port are improved.

10. Industrial production of part of the spare parts and the creation of more skilled jobs for trained workers are encouraged.

11. Machines for the small farms as well as for large units are developed.

12. Favorable prices of petroleum fuels encourage the use of engine power.

13. A labor shortage for tillage, transplanting, weeding and harvesting, creates production bottlenecks and causes reduction in yields or crop losses.

14. A shortage of work animals because of insufficient numbers, disease, improper training, insufficient size or strength, or the increased market for

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[18] H.J. Braun, *Niger: Agricultural Small Tools, Progress Report* (Rome: Food and Agricultural Organization of the United Nations, February, 1963), p. 1.

quality meat favors transition.

15. The poor condition of work animals at the end of the dry season and the beginning of land preparation favors transition.

16. Animal power cannot expand timely operations with only indigenous implements, when animals are unable to break and seed sufficient land in the limited time available after the first rains (in Africa, this is a prime reason for introducing engine-powered equipment).

17. The development of large land areas of high agricultural potential with low labor population density, and scarcity or non-availability of animal power.

18. The very rapid regrowth of tropical vegetation in areas of high seasonal rainfall, makes weed control impossible by simple cutting, burning or hoeing with hand- or animal-powered tools.

19. A strong program of adaptive research to develop better tools and methods for specific local conditions or to solve particular problems or bottlenecks is needed.

20. The need for and versatility of engine power for stationary operation of mills, threshers, irrigation pumps, as well as for field operations and road transport is noted.

21. The existence of sufficient demand to permit the full utilization of machines or implements on the farmers' land or for contract work for others. Single-purpose machines and expensive power units must be used as many hours a day as possible throughout the year.

22. Favorable attitudes of farmers encourage cooperative ownership of machinery for harvesting and threshing when cost, areas, and timeliness limits prohibit individual ownership of machinery or the completion of each farmer's work.

23. The introduction of new enterprises to employ labor saved and to intensify farming by increasing production per land and labor unit is possible.

24. The intensification of agriculture from a one-crop system to a double- or triple-cropping system where timing, speed of work and superior management become critical. Under these conditions hand and animal power are unable to do all the work even on small areas.

25. The availability of low-cost, well-designed machines, including the small tractor, offers appropriate power to achieve timeliness in operations without sacrificing quality of work.

26. Distribution of improved tools at the farm market level soundly are supported by an effective network of servicing dealers.

Economic Appraisal

The major economic considerations in the establishment and improvement of each system, have been discussed in Chapter IV. Such considerations must be taken into account in introducing new technology in order to assess the probability of success or failure, and the probable economic effects on local and national economies.

Improved technology implies improved productivity and, in the right economic framework, improved income to the producer. This is important in the utilization of more sophisticated levels of power since the higher costs of greater productivity have to be met out of income. Thus, any approach to improvements and mechanization of agricultural technology must take into consideration simultaneously economic as well as the technical factors.

General Economic Framework

The agricultural systems which have been discussed are in dynamic equilibrium: over the long run the pattern of production will shift to accommodate the pattern of consumption, although in the short run movements may be quite violent due to sudden shifts in exogenous variables. Any change in a system's technology to incorporate an increased application of mechanized technology also will increase the level of production for the system, (or conversely, the amount of leisure enjoyed by the labor force) and therefore, shift the dynamic equilibrium of the system. Thus, *there must be adequate incentives in the system to encourage a higher level of production, and to adjust the system to a new dynamic equilibrium*, before any attempts are made to introduce new forms of mechanized technology. This will require the development or exploitation of the export potential from the area under consideration (*i.e.* the marketing of surplus production in the national or international markets).

The general economic framework for hand-powered agriculture does not appear to be sufficiently well-developed to support the marketing of substantial surpluses. In the case of Agnale village, market infrastructure and any concept of a monetized economy are non-existent; the economy of the Zuarungu district would support a higher level of mechanization but at present there exist serious inhibiting factors such as adverse prejudices against using oxen, and an inadequate farm structure; in northern Nigeria the market system may accommodate surplus production but the transition from hand- to animal-powered agriculture is unlikely to occur easily or naturally, and social factors exist which disfavor the use of animals for power. For these reasons, consideration also should be given to the possibility of introducing new commercial enterprises into these localities. In this way an economic catalyst can be fostered to facilitate the development of economic infrastructure

and offer alternative employment in areas of apparent static equilibrium.

The general economic framework of the Chilalo Awraja of Ethiopia already contains the rudiments of a market economy. The utilization of a sophisticated mechanization and the potential for increasing production are likely to force a commensurate balance in development of infrastructure and marketing facilities, provided economic development is allowed to continue. The area is ideally suited for experimentation and development of engine-powered technology, although animal power prevails. Export potential at present is approximately equal to imports into the area. Thus, increases in surplus production may have to be channelled into new enterprises in the area such as milk and beef production and other animal enterprises to consume grain surpluses.

The case in Zuarungu, Ghana represents one in which further expansion is unlikely until additional power can be employed. Oxen are being accepted slowly and yet the general economic framework of existing markets and communication facilities could support technological improvement. *Both experimentation and training facilities for oxen cultivation techniques are required, assuming that unfavorable sociological problems can be overcome.*

The Tanzanian experience demonstrates the need to develop a general economic framework to support the use of animal-powered technology where engine-powered technology has generally proved to be uneconomical.

The two Ethiopian cases of commercial agriculture are fully integrated into a market economy and, *ceteris paribus*, output will be directed by market price fluctuations. In both Tendaho Plantations and the Setit-Humera area, engine-powered technology is appropriate to the economy of operation and the systems have led to substantial employment of hand labor. Export potential in both cases is essential. For the general economy of the country, *greater benefits may be derived from large-scale mechanized farming if an integrated agricultural policy can be developed to facilitate exporting high quality products into the world market, and marketing inferior products domestically.*

The Middle Awash Settlement Scheme has been based on a sound market for cotton. The quality of land and the area available appears suitable for development of engine-powered agriculture, supplemented with hand labor. During the development period, contentions with local inhabitants have been minor. Greater difficulties are likely to emerge from a general scarcity of diligent field workers, frustrations of local management, and financial difficulties of meeting budget commitments.

Appropriateness of the Mechanization Level in Relation to the Local Economy

Appropriateness is related to the achievable level of management by farmers (with extension assistance, if necessary) in an agricultural system.

For large commercial enterprises a sophisticated level of engine-powered mechanization is appropriate, but concomitant elements of intensive management are necessary along with supportive infrastructure and substantial markets.

This level of mechanization may be introduced by a commercial enterprise which can remain fairly isolated from the surrounding economy. An attempt to introduce a new level of mechanization into an already established system is represented in the situation faced by the CADU operation in Ethiopia, the Christian Service Committee in Ghana and the operation of tractor-hire services in several different countries. This form of development has to begin with a general assessment of the system's potential and the additional factors to be grafted into the system before the new level of mechanized technology will be appropriate. Such an assessment requires careful appraisal of local infrastructure, extension and training facilities, and the managerial potential of local farmers. Compensatory factors can be introduced into the system where inadequacies exist, such as training and extension facilities where farmers' educational levels, repair and maintenance services, credit and market facilities are generally inadequate.

Impact of Infrastructure on the Local Economy

The infrastructure serving the local industry has also an important impact on the overall organization of the local economy. A certain minimum infrastructure usually is a prerequisite to a new level of technology and the existing infrastructure has to be expanded to permit the economy to develop. *In all cases the infrastructure has an important secondary effect on the activities of the local economy.*

Roads and railways have obvious impact on the local economy. Experimentation and dissemination of technical knowledge from locally established research stations and local schools has a profound effect on developing the potentials of an area. Repair and maintenance services, established as a functional part of a large organization, have a similar effect since they also can serve the local economy. In small-scale animal-powered and hand-powered economies, where local accumulations of capital are very small, the infrastructure must be improved by outside organizations. In those areas which already have a rudimentary infrastructure, such as in the Chilalo Awraja in Ethiopia and the village economy of northern Nigeria, improvement in the infrastructure may lead to rapid development of the local economy and stimulation of local innovation.

Large-scale operations require an infrastructure which automatically serves the locality. Teaching and training facilities established by the operation also function as a reservoir of local technical expertise.

Lack of credit and banking facilities appear almost universally throughout Equatorial Africa to be severe restraints on economic development. In Setit-Humera, Ethiopia, lack of credit and the exacting requirements for collateral are the most serious of farmers' problems. In hand-powered and animal-powered systems, lack of credit prohibits even the simplest innovation, despite the farmers' appreciation of the innovation's significance. Large commercial organizations, able to raise funds on the local and international stock exchanges, can experience constraints to their preferred rate of expansion through the lack of ready capital.

Large-scale Operations as Employment Generators

Involvement of people in the monetized system is a major factor in expanding the economic base of a country. *Large-scale engine-powered commercial operations can make a particular contribution to raising employment.* The employment of a large labor force at certain periods of the year has important economic ramifications in the financial stimulus such an operation can give to the local economy.

The Importance of Size

Expanding agricultural production is an entrepreneurial function which calls for innovation in both the production function (*i.e.* new inputs and technology) and management. *Smallness in size of operation has been observed to be a limiting factor to the scope for mechanization;* yet to enlarge an operation necessitates not only an outlet for increased production, but also greater management skills. Size and fragmentation frequently act together as constraints. Farm structure is determined by a variety of sociological and economic factors which cannot be ignored in considering the scope for mechanization in any given system.

In hand-labor economies the latitude for experimentation is extremely limited. Therefore, *attempts to innovate are rare; experimentation and the demonstration of results has fallen necessarily into the province of external agencies.* The ability with which these organizations (extension services, training institutions and local commercial enterprises) are able to win the interest and confidence of local farmers can have considerable influence on the scope for mechanization in small-scale hand-labor economies.

There is more scope for small entrepreneurs to innovate in animal-powered systems. Indeed, this is the main objective of extension services in holding demonstrations of new farming techniques, such as the use of new equipment, seeds, fertilizers, on successful farms. Here again, however, genuine innovation is largely undertaken by external agencies. Small farmers operating

at the levels of Chilalo Awraja, Ethiopia, Zuarungu, Ghana, and in the northern Nigerian village lack economic freedom to experiment.

In commercial enterprises the entrepreneur and the innovator are often the same individuals although they may differ organically in different situations, as in the two Ethiopian cases. Tendaho Plantations represents a system in which management is responsible for innovations to exploit the economic situation. However, in Setit-Humera, the original innovations of the area were introduced by the individual farmers; and the area is currently in need of more innovations to build an adequate infrastructure for the present level of development.

Large-scale commercial farming systems expect to gain from potential economies of scale. The individual small farmer in the vicinity of the Tendaho Plantations is not in a position to develop economies of scale. The cotton market is sufficiently buoyant to support the development of a large-scale operation, hence, the Tendaho management is in a strong position to create the necessary infrastructure.

Economies of scale also underlie the success of settlement schemes, tractor-hire services and the block farm schemes. The principal objective of all these types of operation is to provide engine power in an essentially hand-powered system, to remove labor bottlenecks and bring into production land too difficult for hand or animal power.

Agricultural mechanization in the context of abundant hand labor can create conflict. On the one hand, developing economies need new opportunities for employment; this can be achieved by mechanizing some of the productive processes and employing hand labor extensively at certain seasons. On the other hand, failure to completely mechanize the productive process tends to underutilize the full potentials of engine power, and underexploit potential economies of scale.

Economies of scale are elusive factors. They may be the underlying basis of success but they cannot be realized without intensive, well-trained management.

Differentiated Approach to Improved Technology

De Wilde raised the important issue that several approaches to economic development may be appropriate in any one area. Local farmers can be involved simultaneously in different levels of development according to their facilities and level of understanding.[19] A fairly sophisticated development scheme may be appropriate to develop infrastructure in an area, while the local farmers also may be involved in a less sophisticated program. Chilalo Awraja

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[19] De Wilde, *op. cit.*, p. 441.

is an example of a differentiated approach; the CADU program has attempted simultaneously to introduce engine-powered technology and to improve the extant animal-powered technology.

Factors Favoring and Limiting Mechanization

Certain factors in the mechanization process are specifically relevant to each of the levels from hand to engine power, but most factors have general relevance. In many cases the presence of a factor has one effect and its absence has the opposite effect. All the factors tend to be interrelated; the effect of any one factor can only be determined in relation to the presence or absence of several others.

Relationship of Costs and Returns

Mechanization of agricultural technology must also be accompanied by an increase in returns to cover any increased costs. Improved technology should raise agricultural productivity; the economic system should be capable of absorbing it. Increasing agricultural productivity involves any one or a combination of technical factors which raise yields and reduce production costs. The surplus has to be disposed of in a way that acts as an incentive to the farmer to increase his output. Thus, *the mechanization process immediately requires planners to take the macro-economic problem of effective demand into account. If effective demand is inadequate, there is no incentive for the farmer to increase production.* Market channels and economic infrastructure are vital considerations in any proposals to change levels of mechanization.[20]

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[20] In the Third Five Year Development Plan of Ethiopia, the Imperial Ethiopian Government specifically states that the development of commercial agriculture is the only way to produce quick increases in agricultural exports and that it is from this more dynamic sector that rapid gains might be expected. With this in mind, the Agricultural Division of USAID/Ethiopia has prepared a farm development project for the Shashamanne area in the extreme south of Arussi Province and the northern part of Sidamo Province. The long-term objective is to involve medium- and small-sized farmers in a system of commercial farming based on a market economy. Facilities are to be created for the introduction of appropriate machinery into the area although mechanization is not, *per se*, the objective of the project. The heart of the project is provision of supervised credit to be used for the purchase of farm machinery, tools, fertilizer, chemical and improved seed.

The Ethiopian Grain Corporation is expected to establish a marketing and storage facility in this area to handle increases in production. Cropping patterns are designed to avoid overproduction of any commodity which would tend to overload the potential market. The largest relative increase is planned for the area of haricot beans because of strong demand on the world market. However, the project stands or falls on the establishment of an adequate market for the substantial increase in maize production which is planned since this is the principal crop to be grown.

Management Skills

Raising the level of mechanization necessitates both a more sophisticated level of management and more modern inputs; with animal- and engine-powered farming the availability of these factors becomes much more critical. *The level of farmers' education is a critical factor in the type of mechanization which they can handle. Compensations for some inadequacies can be introduced through an effective extension service.* In the hand- and animal-powered systems, extension officers become involved deeply in local leadership and technical innovation. Local extension agents should be vigilant to identify local potential innovators who can play a lead in development of their area.

Thus, demands for greater management ability are bound up in education, training and educational achievement of leading individuals. The presence of good local training facilities and schools becomes increasingly important as the level of mechanization becomes more sophisticated, otherwise, technicians and managers must be brought in from outside. The system of education in a rural area can have a profound influence on future development through teachers' attitude and the general orientation of the curriculum. A bias in the curriculum toward urbanized society and its cultural interests, at present frequently observed in rural African schools, is not conducive to maintaining gifted young peoples' interests in the potential prosperity of the rural society in which they were raised. *Curricula of rural schools, and agricultural training schools usually established for more senior students and adult education, should include interesting courses relevevant to the local economy; this requires school faculties which also have a genuine interest in rural development.*

Availability of Modern Inputs

The necessity of obtaining modern inputs easily and promptly becomes increasingly important. Timeliness of cultivation and heavy overhead costs make availability of supplies more critical. Thus, supportive infrastructure must be adequate for the level of development. Repair, maintenance, and fuel supply services are a necessity with engine-powered agriculture; inadequate credit facilities seriously inhibit large-scale operations; a critical shortage of local hand labor renders impossible a partially engine-powered system; inadequate road transport and communications make haulage of produce extremely expensive; inadequate extension advisory services lead to failure to exploit the local agricultural potential and to obtain optimum service from agricultural equipment; the absence of adequate research facilities leads to insufficient technical information on which to base extension service recommendations.

Large-scale Economic Catalysts

Large-scale commercial operations frequently have been referred to as potential economic catalysts for development since they can stimulate the development of a local infrastructure. Gradually smaller, less mechanized agricultural systems will orient their production toward a market. *This form of stimulus, however, is only likely to meet with success if a properly differentiated approach is adapted.* Without positive effort to improve indigenous agriculture near a large-scale commercial operation, *the local and the commercial economy can co-exist indefinitely, each having little impact on the other.*

Farm Structure

Farm structure remains as a significant factor in potential development. The farms of hand-labor economies frequently are too small and too fragmented to facilitate the economical employment of tools at another level of mechanization. *Inflexibility of farm structure and land-tenure arrangements can impose serious constraints.*

Local-based Adaptive Research and Demonstration

In areas of predominantly hand-labor and animal-powered economies, any innovation in the use of tools, equipment and cultivation practices should be based on local adaptive research. *Courses in training institutions, schools and farm demonstrations should be presented in terms of reference familiar and relevant to the local situation.* Despite the general applicability of much agricultural research in both agronomy and mechanization, *local adaptive research should be very specific in attempting to solve local agricultural problems.*

Lack of Monetization

A major limiting factor of technological development in hand-labor economies is lack of monetization. Money is the medium by which any economy develops into an integrated market system. A hand-labor economy cannot dispose of surplus production if the concept and use of money has not been incorporated into the economic thinking of the people.

Adequate effective demand is vital to development in Equatorial Africa. Without an adequate market it is impossible to effect a program of mechanization with any reasonable expectation of success. *Effective demand requires effective articulation of the economy between producers and consumers and a functional medium of exchange.* Technological development in agriculture can proceed only as the economic base of the country is expanded to draw more of the entire nation into the monetized economy.

Associated Social Factors

Local prejudices, preferences and attitudes are frequently found to inhibit certain kinds of technological development. *Associated social factors should be recognized, understood in the social context of the area, and incorporated into development programs as relevant variables along with the complex of technological and economic factors.* A program of technological improvement has more likelihood of success when recognition of social attitudes is built into the plan: those attitudes being acknowledged as a reality in the lives of the people involved.

Conclusion: Role of Mechanization in Agricultural Development of Equatorial Africa

Introducing improved technology and mechanization into present farming systems involves a complex of interrelated factors which separately or together can favor or limit the process. It is a task of major importance to determine which are the relevant factors in each specific case. Not all factors included in this discussion are relevant to every case and levels of importance will vary.

The broad spectrum of factors indicates the extent of necessary expenditure which can be required for a completely integrated development program. Underwriting the cost of such a program becomes a heavy burden on sponsoring authorities and favors fairly concentrated well-integrated programs with a complete "package-deal" approach over a relatively long period of time, in contrast to relatively short-term highly specialized programs.

In most African situations there is no advantage, at present, in using a mechanized technology to substitute for abundant labor. When labor bottlenecks appear at periods in the crop calendar, mechanization can overcome temporary labor shortages. Where marginal costs of increasing land productivity are less than marginal costs of clearing new land, for a given output, mechanization can be used as a substitute for land.

Added power, however, increases productivity only in combination with other inputs. Mechanized technology makes economies of scale more readily attainable, thereby reducing unit costs of production; it can improve quality and timeliness of cultivation practices and lead to yield improvements. Other inputs also are directly responsible for improving production. Mechanization, especially at the level of engine-powered technology, can be achieved only in the context of a commercial agriculture in which farmers' management skills are well-developed.[21] Through the management function the role of mechanization

[21] Boshoff recommends that no attempt should be made to introduce a form of mechanized (tractorized) technology unless farmers are inclined toward a form of business farming and have developed adequate levels of management ability.
W.H. Boshoff, "Farming Systems in Africa: Mechanization of Agriculture", *Agricultural Research Priorities for Economic Development in Africa*, Vol. III (Washington, D.C.: National Academy of Sciences, 1969).

is related to other factors in the production function.

Operation of the factors which favor and limit mechanization in the context of the agricultural system must be understood. Adequate technical information is vital to operation of different types of equipment at different levels of mechanization. *As one factor in combination with others, mechanization has a particular place in the order of priorities for developing different systems of agriculture. The priority for mechanization frequently is not of the first order.*

In the development of Equatorial African agriculture the role of mechanization should be carefully assessed. There is need for a functional research facility able to achieve the following objectives:

1. To disseminate relevant technical information on types of agricultural mechanization; this will assist local, regional and national planners to understand the technical problems involved in operating agricultural equipment and the role which mechanization plays in a given situation.

2. To determine an order of priorities for research relative to a given program of development, and thus the order of importance that research into mechanization problems should have.

3. To assist research conducted by national research institutions to generate relevant scientific data which is necessary for improvement of national farming systems with mechanical assistance.

4. To coordinate research work so that relevant data are made available to different regions with similar environmental conditions.

5. To conduct research in mechanical handling, storage, processing and transportation of specific marketable agricultural produce.

The Recommendations and Guidelines in Part One are intended to suggest how these objectives can be achieved. The role of mechanization has been construed in terms of technological research at both the regional and national level. Regional cooperation in research may be beneficial in countries faced with similar agricultural problems and having similar ecological environments. Much agricultural research, however, is very specific only to limited geographical areas. Therefore, although regional cooperation and the regional dissemination of research findings can be mutually beneficial, such proposals must be based on the sound operation and cooperation of national research facilities.

APPENDIX I

COMMON AND SCIENTIFIC NAMES OF PLANTS

Common Name	Scientific Name
Bambara nuts (beans)	*Voandzeia subterranea*
Bamboo family of *Gramineae* and more than 14 genera. At least 2 genera have been reported in Africa	*Arundinaria* species and *Dendrocalamus* species
Banana	*Musa sinensis*
Barley	*Hordeum* species
Bean, broad	*Vicia faba*
Bean, haricot	*Phaseolus vulgaris*
Breadfruit	*Artocarpus communis*
Broad bean	*Vicia faba*
Cacao (Cocoa)	*Theobroma cacao*
Cashew nut	*Anacardium occidentale*
Cassava	*Manihot utilissima*
Castor	*Ricinus communis*
Chick-pea	*Cicer arietinum*
Chillies (peppers)	*Capsicum annuum*
Citrus	*Citrus* species
Coconut	*Cocos nucifera*
Cocoyam (taro) (arum) (dasheen)	*X anthosoma sagittifolia* and *Colocasia esculenta*
Coffee	*Coffea arabica* and *C robusta*
Congo jute	*Urena lobata*
Corn (maize)	*Zea mays*
Cotton	*Gossypium arboreum*, *G. herbaceum*, *G. hirsutum*, and *G. barbadense*
Cowpea	*Vigna sinensis*
Custard-apple	*Annona reticulata*

Common Name	Scientific Name
Elephantgrass (napiergrass)	*Pennisetum purpureum*
Ensat (ensete, plantain)	*Ensete edule*
Ensete (ensat, plantain)	*Ensete edule*
Fig	*Ficus* species
Flax (linseed)	*Linum usitatissimum*
Ginger	*Zingiber officinale*
Groundnut (peanut)	*Arachis hypogea*
Guava	*Psidium* species
Guineacorn	*Sorghum guineense*
Horse bean	*Vicia faba*
Hyparrhenia	*Hyparrhenia dissoluta* or *H. rufa*
Jackfruit	*Artocarpus integrifolia*
Jujube	*Zizyphus jujuba* or *Z. vulgaris*, or *Z. Mauritiana*
Jute	*Corchorus capsularis* and *C. olitorius*
Jute, Congo	*Urena lobata*
Kapok	*Ceiba pentandra* and *Bombax* species
Kenaf (rama) (mesta)	*Hibiscus cannabinus*
Kikuyugrass	*Pennisetum clandestinum*
Kola nut (cola nut)	*Cola acuminata*, *C. verticillata*, and *C. nitida*
Kudzu, tropical	*Pueraria phaseoloides*
Lentil	*Lens esculenta*
Linseed (flax)	*Linum usitatissimum*
Maize (corn)	*Zea mays*
Mango	*Mangifera indica*
Melon	*Citrullus vulgaris*
Millet, African	*Eleusine coracana*
Millet, pearl (coos)	*Pennisetum glaucum* (formerly known as *Pennisetum typhoidem* and *P. spicatum*)

Common Name	Scientific Name
Molassesgrass	*Melinis minutiflora*
Niger (nug)	*Guizotia abyssinica*
Nug (niger)	*Guizotia abyssinica*
Okra (Okro)	*Hibiscus esculentus*
Oil palm	*Elaesis guineensis*
Pangolagrass	*Digitaria decumbens*
Papaya (pawpaw)	*Carica papaya*
Paragrass	*Panicum purpurascens*
Pawpaw (papaya)	*Carica papaya*
Pea	*Pisum sativum*
Peanut (groundnut)	*Arachis hypogen*
Pearl millet (coos)	*Pennisetum glaucum* or *P. typhoideum*
Pepper, red (chillies)	*Capsicum annuum*
Pineapple	*Ananas sativa* and *A. comosus*
Potato	*Solanum tuberosum*
Pyrethrum	*Pyrethrum* or *Chrysanthemum cinerariaefolium*
Red pepper	*Capsicum annuum* and *C. frutescens*
Rhodesgrass	*Chloris gayana*
Rice	*Oryza sativa*
Rubber	*Hevea braziliensis*
Sunflower	*Helianthus annuus*
Speargrass	*Imperata cylindrica*
Safflower	*Carthamus tinctorius*
Sesame (benniseed)	*Sesamum indicum*
Shea butter tree	*Butyrospermum parkii*
Sisal	*Agave sisalana*
Sorghum, grain	*Sorghum vulgare*
Soybean (soya bean)	*Glycine soja*

Common Name	Scientific Name
Sugarcane	*Saccharum officinarum*
Sunflower	*Helianthus annuus*
Sweet potato	*Ipomoea batatas*
Tamarind	*Tamarindus indica*
Taro (cocoyam) (arum) (dasheen)	*Xanthosoma sagittifolia* and *Colocasia esculenta* and *C. antiquorum*
Tea	*Camellia* species
Teff	*Eragrostis abyssinica*
Tobacco	*Nicotiana tabacum*
Turmeric	*Curcuma longa*
Wheat	*Triticum* species
Yam	*Dioscorea* species
White yam	*Dioscorea rotundata*
Yellow yam	*D. cayenensis*
Water yam	*D. alata*

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APPENDIX II

A. Units of Measure

1. Area

1 hectare (ha.) = 2.47 acres

2. Weight

1 kilogram (kg.)	= 2.20 pounds
1 metric quintal (q.)	= 100 kilograms
	= 220 pounds
1 metric ton	= 0.98 long tons = 2240 pounds
	1.10 short tons = 2000 pounds
	=1000 kilograms

3. Yield

100 kilograms per hectare (kg./ha.) = 1.49 bushels (60 pounds) per acre

4. Liquid Measure

1 liter (l.) = 0.26 U.S. gallons

5. Length

1 meter (m.)	= 1.09 yards
1 kilometer (km.)	= 0.62 miles
1 centimeter (cm.)	= 2.54 inches

6. Pressure

1 kilogram per square centimeter (kg./cm.^{2}) = 14.22 pounds per square inch

B. Units of Currency Used in This Report

1. Ethiopia

E$1.00 = U.S. $0.403   U.S.$1.00 = E$2.48

2. Gambia

G£ 1. 0s. 0d. (Gambian pounds, shillings, pence) = U.S.$2.40
20 shillings = 1 pound
12 pence = 1 shilling

U.S.$1.00 = G£ 0.417

3. Ghana

N¢ (new cedis) 1.00 = U.S.$0.976   U.S.$1.00 = N¢ 1.025

4. Ivory Coast and Senegal

1 franc CFA (Communauté Financière Africaine) = U.S.$0.004082

U.S.$1.00 = 245 francs CFA

5. Kenya, Tanzania, Uganda

1.0 shilling = U.S.$0.1405   U.S.$1.00 = 7.12 shillings
20 shillings = 1 pound

6. Nigeria

N£ 1. 0s. 0d. (Nigerian pound, shillings, pence) = U.S.$2.80
(same currency system as Gambia)

U.S.$1.00 = N£ 0.357
(= N£ 0. 1s. 7.4d.)

APPENDIX III

ABBREVIATIONS

APO	Asian Productivity Organization (Japan)
AGRIDEV	Agricultural Development International (Israeli private cooperative)
AFLOS	Trade name for a British-made multi-purpose animal-drawn toolbar
ASAE	American Society of Agricultural Engineers (United States)
AVA	Awash Valley Authority (Ethiopia)
BDPA	Bank Development Projects Agricultural (Tanzania)
BEWAC	British East and West Africa Company (Nigeria)
BSRAE	British Society for Research in Agricultural Engineering (United Kingdom)
CADU	Chilalo Agricultural Development Unit (Swedish development program in Ethiopia)
CAP	Certificat d' Aptitude Professionale
CAR	Central African Republic
CEEMAT	Centre d' Etudes et d' Experimentation du Machinisme Agricole Tropical (France)
CENTO	Central Treaty Organization (Iran, Pakistan and Turkey)
CFA	Communauté Financière Africaine (monetary system of Ivory Coast and Senegal)
CFAO	Consolidated French Africa Organization (Ivory Coast)
CIDMA	Centre International de Documentation du Machinisme Agricole (France)
CIGR	Commission International de Génie Rurale (France)
CNEEMA	Centre National d' Etudes et d' Experimentation du Machinisme Agricole (France)
CSC	Christian Service Committee (Ghana)
CSIR	Council for Scientific and Industrial Research (Ghana)
CSNRD	Consortium for the Study of Nigerian Rural Development
EAAFRO	East Africa Agricultural and Forestry Research Organization (Kenya)
EAC	East African Community (Kenya, Tanzania and Uganda)

EACSO	East Africa Common Services Organization (Kenya, Tanzania and Uganda)
EANRRC	East African Natural Resources Research Council (Ethiopia)
EATITU	East African Tractor and Implement Testing Unit (Kenya)
EATU	East Africa Testing Unit (formerly under EACSO)
ECA	Economic Commission for Africa (Ethiopia)
FAO	Food and Agricultural Organization, United Nations (Rome)
FMC	A United States farm machinery manufacturer
GAS	Ghana Academy of Science
GON	Government of Nigeria
IAR	Institute of Agricultural Research (Ethiopia)
IAR	Institute for Agricultural Research (Nigeria)
IBRD	International Bank for Reconstruction and Development (United States)
ICAE	International Commission of Agricultural Engineers (see CIGR) (France)
IDC	Industrial Development Center (Nigeria)
IEG	Imperial Ethiopian Government
IITA	International Institute for Tropical Agriculture (Nigeria)
IRAT	Institut de Recherches Agronomique Tropicale et des Cultures Vivrières (Senegal)
IRRI	International Rice Research Institute (Philippines)
KAMU	Kenya Agricultural Machinery Unit
KTHS	Kenya Tractor Hire Service
MOA	Ministry of Agriculture
Motoragri	Motorized Agriculture Organization (Ivory Coast)
NDCA	National Development Council for Africa
NIAE	National Institute of Agricultural Engineering (United Kingdom)
NISER	Nigerian Institute for Social and Economic Research
OAU	Organization for African Unity (Ethiopia)
SAFIM	South Africa Farm Implement Manufacturers
SISCOMA	Société Industrielle Sénégalaise de Constructions Mécaniques et de Materiels Agricoles
SRI	Stanford Research Institute (United States)

TAMTU	Tanzania Agricultural Machinery Testing Unit
THU	Tractor Hire Unit (Ghana)
TPRI	Tropical Pesticides Research Institute (Tanzania)
UAC	United Africa Company (Ghana)
UNDP/SF	United Nations Development Program, Special Funds Project
USAID	United States Agency for International Development
USAID/E	United States Agency of International Development (Ethiopia)
VITA	Volunteers International Technical Assistance (United States)
WARDA	West African Rice Development Association (proposed)
WIP	World Indicative Plan (FAO/UN Rome)

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